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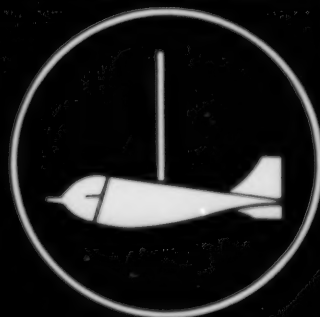
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ALBERTA
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ENVIRONMENT

**PROCEEDINGS OF THE ALBERTA
SEDIMENT ISSUES WORKSHOP:
SEPTEMBER 27-28, 1988
CALGARY, ALBERTA**

T.R. YUZYK, N.F.R. CHAPIN



WATER RESOURCES BRANCH
INLAND WATERS DIRECTORATE

DIRECTION DES RESSOURCES EN EAU
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Western and Northern Region

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Your file Votre référence

Our file Notre référence

1989 03 31

6700-1/SED-3

Participant
Alberta Sediment Issues Workshop
September 27-28, 1988
Calgary, Alberta

Dear Participant:

Re: Workshop Proceedings

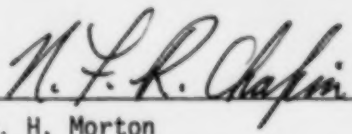
Enclosed is your copy of the 'Proceedings of the Alberta Sediment Issues Workshop' held in Calgary on September 27 and 28, 1988. The proceedings contain the papers, comments, and issues which were presented and/or addressed during the 1-1/2 day seminar.

I want to take this opportunity to thank you very much for taking the time to attend the 1988 Alberta Sediment Workshop. I trust that you enjoyed it and found the presentations to be informative, while at the same time adequately addressing your particular interests in sediment.

Mr. Chapin, the co-ordinator, would be very interested in any suggestions which you might have to improve either the format and/or the content of the workshop. Any comments on the sediment program, in general, would also be greatly appreciated. We're especially interested to find out your ideas concerning the current format in which we offer our data. Any comments which you would be able to provide in order to improve its usefulness would be helpful.

Once again, thank you for your involvement with the workshop and we look forward to the opportunity of addressing any of your sediment concerns in the future.

Yours sincerely

for 
G. H. Morton
Chief
Alberta District

Encl.

Canada

Proceedings of the Alberta
Sediment Issues Workshop:
September 27-28, 1988
Calgary, Alberta

by

T.R. Yuzyk¹ and N.F.R. Chapin²

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March, 1989

Abstract

It is apparent from the workshop that the problems relating to sediment are very diverse and in many cases a multidisciplinary approach is required to comprehend the magnitude of the problem. Numerous issues in Alberta relating to streamborne sediments were identified at the workshop. In the agricultural sector, erosion caused by water was found to be a significant problem and considerable research is being done to better understand the mechanics of the problem. As this eroded material enters the waterways, it affects the stream dynamics and channel morphology, which impacts on numerous engineering projects. This sediment may also be transporting contaminants which affect the water quality and the aquatic ecosystem. This consequently has detrimental effects on fisheries.

The workshop also focused on providing information on sediment-related programs delivered by key government agencies, showing how these agencies interact and providing insight into the future direction of these programs. Part of the workshop was spent on highlighting current initiatives of the Sediment Program which is cost-shared between Alberta Environment (River Engineering Branch) and Environment Canada (Water Resources Branch).

Résumé

Il est évident, à la suite de l'atelier, que les problèmes reliés aux sédiments sont très diversifiés et, dans de nombreux cas, qu'une approche multi-disciplinaire s'avère nécessaire pour comprendre l'ampleur du problème. Un grand nombre de questions ont été identifiées au cours de l'atelier se rapportant aux sédiments fluviaux en Alberta. Dans le secteur agricole, l'érosion entraînée par l'eau constitue un problème considérable et il se fait beaucoup de recherche pour mieux comprendre les mécanismes de cette situation. Lorsque le matériel érodé s'introduit dans les débouchés, il influe sur la dynamique du cours d'eau et sur la morphologie du canal, ce qui entraîne des répercussions sur beaucoup de projets de génie. Ces sédiments peuvent aussi transporter des substances contaminantes qui ont une incidence sur la qualité de l'eau et l'écosystème aquatique. Les conséquences sont donc fâcheuses sur l'industrie des pêches.

Les participants à l'atelier se sont également attardés à offrir de l'information sur les programmes liés aux sédiments appliqués par des organismes gouvernementaux-clés, démontrant les interactions entre ces organismes et donnant une perspective de l'orientation future de ces programmes. Une partie de l'atelier a été consacrée aux points saillants des initiatives actuelles du programme sur les sédiments dont les coûts sont partagés entre la direction du génie hydraulique d'Environnement Alberta et Environnement Canada (Direction des ressources en eau).

Acknowledgments

We are extremely grateful to G. Morton for his entertaining anecdotes given while chairing both the panel and orientation sessions. We would also like to thank all the panel members: T. Day, M. Spitzer, R. Quazi, D. Andres, T. Dafoe, A. Cullen and A. Locke for the insights they provided on their respective organizations and programs. The orientation session speakers: T. Day, M. Cashman and R. Yungvirth contributions are much appreciated, as well as all the help provided by other WRB staff in setting up displays and the meeting facilities.

Also, we are very appreciative of all the effort H. Hudson put into organizing and chairing the technical session. Special thanks are due to all the technical speakers: R. Hovitt, I. Campbell, G. Beckstead, L. Linton and B. Bietz for their highly informative presentations.

Contents

	Page
Letter of Transmittal	
Abstract/Résumé	i
Acknowledgments	ii
1. Introduction	1
1.1 Purpose	1
1.2 Agenda	2
2. Orientation Session	6
2.1 National Sediment Program (T.J. Day)	6
2.2 Alberta Sediment Program (N.F.R. Chapin)	9
2.3 Data Collection and Processing (M.A. Cashman)	14
2.4 Laboratory Analysis (R.H. Yungwirth)	18
2.5 Data Interpretation (T.R. Yuzyk)	23
2.6 Sediment Program Outputs (M.A. Cashman)	29
3. Technical Session	31
3.1 Fluvial Sediment - Contaminant Cycling: An Overview (H.R. Hudson)	31
3.1.1 Contemporary Contaminant Problems	32
3.1.1.1 Types and Sources of Contaminants	32
3.1.1.2 Sediment Contaminant Interactions	33
3.1.1.3 Biotic Contaminant Interactions	36
3.1.2 Implications for Water Quality Assessments	37
3.1.3 Workshop Presentations	38
3.1.4 Conclusions	39
3.2 Erosion from Upland Sources (R.W. Howitt)	40
3.2.1 Processes of Soil Erosion	40
3.2.2 Approaches to Measuring Soil Erosion	42
3.2.3 Upland Erosion and the Sediment Cycle	43
3.3 Instream Sediment Transport (I.A. Campbell)	45
3.3.1 Alberta Examples	48
3.3.2 Summary	53
3.4 Uses of Sediment Data in Engineering Projects (G.R.E. Beckstead)	54
3.4.1 Engineering Uses of Sediment Data.....	54
3.4.1.1 Reservoir Studies	55
3.4.1.2 Water Intakes	55
3.4.1.3 Sedimentation Ponds	56
3.4.1.4 Channel Diversions	56
3.4.1.5 Pipeline Crossing	56
3.4.1.6 Other Engineering Uses	57
3.4.2 Sediment Yield	58
3.4.3 Alberta Projects	59

3.5	Importance of Sediment in Water Quality	
	Assessments (L.R. Linton)	61
3.5.1	Suspended Solids, Nutrients and Toxicants	62
3.5.1.1	Adsorption	62
3.5.1.2	Toxicity	63
3.5.1.3	Transport and Deposition	63
3.5.1.4	Fate	63
3.5.2	Suspended Sediments and the Aquatic Biota	64
3.5.2.1	Primary Producers	64
3.5.2.2	Macroinvertebrates	66
3.5.2.3	Fish	67
3.5.3	The Relationship Between NFR and SS	67
3.5.4	Issues	68
3.6	Sediment Impacts on Fisheries (B.F. Bietz)	69
4.	Panel Session	73
4.1	Sediment Survey Section (T.J. Day)	73
4.2	Water Resources Branch (M.O. Spitzer)	78
4.3	Alberta River Engineering Branch (R. Quazi)	83
4.4	Alberta Research Council (D.D. Andres)	86
4.5	Water Quality Branch (T. Dafoe)	90
4.6	Prairie Farm Rehabilitation Administration (A.J. Cullen)	95
4.7	Alberta Forestry, Lands and Wildlife (A. Locke)	98
5.	Summary	106
6.	References	110
	Appendix: Mailing List	116

Figures

	<u>Page</u>
Figure 2.2.1 1988 Alberta Sediment Program	11
Figure 2.3.1 Depth-Intergrating Sampling	15
Figure 2.3.2 Analytical Flow Chart, Suspended Sediment Analysis ..	17
Figure 3.3.1 Generalized Relationship Between Stream Power Transport Capacity and Drainage Area	49
Figure 3.3.2 Flow Chart for Sediment Routing Linking Sources, Sinks and Outputs	49
Figure 3.3.3 Instream Sediment Relationships Showing Inputs, Storage and Outputs	53
Figure 3.4.1 Sediment Yield Versus Drainage Area of World Rivers (Measured Suspended Loads)	59

Tables

Table 2.5.1 Station Management and Information System (SMIS)	24
Table 2.5.2 Station Profiles	25
Table 2.5.3 Station Management Plan (SMP)	26
Table 3.4.1 Uses of Sediment Data in Engineering Projects	54

1. INTRODUCTION

The Water Resources Branch (WRB) of Environment Canada, in cooperation with various provincial agencies, have been involved in organizing sediment issues workshops across Canada. To date, workshops have been held in Guelph (October, 1985), Charlottetown (June, 1986), Winnipeg (November, 1986), Regina (November, 1987) and most recently Calgary (September, 1988).

The Calgary workshop was sponsored by: the Water Resources Branch (Calgary), Sediment Survey Section (Ottawa), Alberta Environment and Alberta Research Council. The workshop dealt primarily with streamborne sediments and focussed on issues and concerns specific to the province of Alberta.

The workshop had a multidisciplinary format and brought together approximately ninety individuals (see mailing list in Appendix). Representatives from universities, federal and provincial governments, private, research and consulting sectors attended the 1 1/2 day workshop.

1.1 Purpose

The workshop was made up of three distinct sessions: orientation, technical and panel. The specific purposes of each session are as follows:

Orientation Session

- update or familiarize sediment data users with the current WRB program

- provide technical advice on equipment, data collection and interpretation

Technical Session

- provide a multidisciplinary focus to obtain a broad perspective on the issues and concerns relating to sediment in the province
- familiarize individuals with studies and on-going monitoring being done in Alberta by various disciplinary groups

Panel Session

- determine how these issues are currently being addressed by the various government agencies
- assess how these agencies interact

1.2 Agenda

The 1 1/2 day workshop was divided into three sessions each being a half day in length (see agenda). The first session was the orientation session. This session was comprised of six presentations given by WRB staff which dealt with: the National sediment program, Alberta sediment program, data collection and processing, laboratory analysis, data interpretation and program products. Also, there were six poster presentations with the following themes:

- Sediment Survey Report Series
- Sediment Survey Plot Package

- Sediment Samplers
- Special (Hydrographic) Surveys
- Laboratory Analyses and Equipment
- Sediment Characteristics of Alberta Streams.

The technical session was made up of six individual presentations given by experts in their respective fields. The session was introduced with an overview of the sediment/contaminant cycle to show linkages between the processes in the system. It was followed by a presentation which focussed on upland erosion and how the sediment is transported from the land to the river system. This led into the next presentation which dealt with the main processes and how they interact within the fluvial environment. The presentations then shift focus from processes to uses of data by various disciplines. Engineering uses of data were shown to be primarily for design purposes. The water quality perspective was concerned with sediment impact on the aquatic habitat and the role of sediment as a transporter of contaminants. Finally, the effect that sediment has on fisheries and the regulatory aspects were addressed in detail. The session was closed with a summary which highlighted the pertinent information from each of the presentations.

The panel discussion involved presentations by seven individuals representing leading government agencies (both federal and provincial). The speakers talked briefly about their organization's mandate, current program initiatives and what they anticipate are the future issues facing their organization. The discussion was then opened to the floor. The session ended with closing comments from various individuals.

1988 ALBERTA SEDIMENT WORKSHOP AGENDA

ORIENTATION SESSION: 1988 September 27 (afternoon) Chairman - G. Morton

- 12:30 - 13:00 Registration - Delta Bow Valley Hotel, Mezzanine, SALON A
13:00 - 13:10 Introductory Remarks G. Morton
13:10 - 13:40 National Sediment Program T. Day
13:40 - 14:00 Alberta Sediment Program N. Chapin
14:00 - 14:20 Data Collection and Processing M. Cashman
14:20 - 14:35 Laboratory Analysis R. Yungwirth
14:35 - 14:50 Data Interpretation T. Yuzyk
14:50 - 15:00 Program Outputs M. Cashman
15:00 - 15:30 COFFEE BREAK
15:30 - 16:30 Poster Presentations & Informal Discussions

TECHNICAL SESSION: 1988 September 28 (morning) Chairman - H. Hudson

- 08:30 - 08:45 Sediment/Contaminant Cycle H. Hudson
(Alberta Research Council)
08:45 - 09:15 Erosion from Upland Sources R. Hovitt
(Alberta Research Council)
09:15 - 09:45 Instream Sediment Transport I. Campbell
(University of Alberta)
09:45 - 10:15 Uses of Sediment Data in
Engineering Projects G. Beckstead
(Hardy BBT Ltd.)
10:15 - 10:45 COFFEE BREAK
10:45 - 11:15 Importance of Sediment in Water
Quality Assessments L. Linton
(Hydroqual Consultants Inc.)
11:15 - 11:45 Sediment Impacts on Fisheries B. Bietz
(Stanley Associates)
11:45 - 12:00 Summary H. Hudson
(Alberta Research Council)

PANEL SESSION: 1988 September 28 (afternoon) Chairman - G. Morton

Panel: T. Day Sediment Survey Section - Ottawa
M. Spitzer Water Resources Branch - Calgary
R. Quazi ADOE, Rivers Engineering Branch - Edmonton
D. Andres Alberta Research Council - Edmonton
T. Dafoe Water Quality Branch - Ottawa
A. Cullen Agriculture Canada, PFRA - Calgary
A. Locke Alberta Forestry, Lands & Wildlife - Edmonton

13:00 - 13:10 Introduction G. Morton
13:10 - 13:15 Organization & Issues T. Day
13:15 - 13:20 " " " M. Spitzer
13:20 - 13:25 " " " R. Quazi
13:25 - 13:30 " " " D. Andres
13:30 - 13:35 " " " T. Dafoe
13:35 - 13:40 " " " A. Cullen
13:40 - 13:45 " " " A. Locke
13:45 - 15:00 General Discussion Audience and Panel
15:00 - 15:30 COFFEE BREAK
15:30 - 16:00 Summary G. Morton/T. Day

2. ORIENTATION SESSION

2.1 National Sediment Program (T.J. Day)

Streamborne sediments are important for their physical characteristics and for what they carry. Traditionally the Water Resources Branch (WRB) sediment monitoring activities have focused upon applications in water resources engineering (e.g. reservoir sedimentation, engineering design). However, we are rapidly developing an appreciation of the role and importance of sediment in environmental quality issues (e.g. fish habitat, water quality). Over the last few years we have learned to work with other agencies dealing with, for example, agriculture and water quality. While these discussions are fruitful they have not as yet lead to any substantive changes to our program.

These sediment monitoring activities are carried out nationally through federal-provincial cost-sharing agreements as part of Water Resources Branch's hydrometric program responsibilities. Our program objectives simply stated are to provide: data on sediment transport; expertise on sediment transport; and to provide standardization of equipment and procedures. The organization of sediment activities is roughly divided with operational responsibilities in the regional offices and the Sediment Survey Section providing technical guidance from Ottawa.

The present activities foci for the program can be grouped as follows:

Information Content

The existing sediment data of WRB, which constitutes the largest in Canada, have not yet been fully utilized. We are attempting to analyze these data with the purpose of learning more about sediment transport characteristics in Canadian rivers - and applying this knowledge to environmental problems such as contaminant transport.

Communications

Considerable effort is being directed towards communications with 'clients'. Workshops like this one represent a major initiative to explain our program, to encourage input from other individuals and agencies (particularly for environmental applications) and to generate interest in sediment-related concerns. Also, through our report series and data publications we are attempting to establish an identity for our program.

Integration

In order to develop and deliver an effective program for sediment-associated contaminant transport, we are presently considering opportunities for integrating our activities with those of the Water Quality Branch of Inland Waters Directorate. A study team has been established to examine these opportunities.

Planning

In order to establish better control over our sediment activities we are implementing a three year national action plan, one element of which is to establish a network planning process. We are now implementing an annual review process for each station's activities. Closer management will permit us greater operational flexibility and is naturally required to ensure effectiveness.

Special Surveys

Our program has a good record of undertaking reservoir surveys (mainly in the Western and Northern Region), and other morphological type surveys. We also have completed river surveys for special studies such as bed degradation below Gardiner Dam on the South Saskatchewan River in Saskatchewan. We plan to become more involved in monitoring and studying long-term channel changes arising from flow alterations.

Studies and Development

We are involved in a range of studies on data interpretations, accuracy and precision of data, computations, sediment sources and yield. Efforts to evaluate and modify sampling equipment continue as well.

Monitoring

The Branch operates approximately 200 sediment stations (there are a further 600 discontinued stations) which continue to focus primarily upon water resources applications. There remains a mix of project and baseline stations. Our major shift in monitoring network 'design' is to reduce the number of long-term data collection stations (due to their limited value) and to increase the number of sites where only a limited number of samples are collected (sufficient to define river conditions).

The program is expected to continue along these directions. Its main benefits will be fully realized only once the role and importance of sediment in environmental quality issues is understood and when appropriate program responses are implemented. Our immediate external concern is to develop linkages with water quality programs. Internally, the development of technical expertise and managerial practices and their implementation, remain paramount.

2.2 Alberta Sediment Program (N.F.R. Chapin)

The objectives of the Alberta program are to obtain good, reliable data which can be used by the engineering, scientific and environmental communities. Currently, we seem to be satisfying, to a large extent, the former, and are now in the process of investigating the feasibility of modifying our Water Resources Branch programs to address the latter.

The Alberta Sediment Program started in 1963, with the Marmot Creek Main Stem station being the first. It was started because of the forest research basin, which began there at about the same time. Willow Creek near Claresholm was added in 1964, Willow Creek above Chain Lakes and others in 1965 and major additions in 1966. It should be noted that the two Willow Creek stations are still active today as miscellaneous stations. In the beginning the stations were run on a regular program basis, but then changed over the years as the miscellaneous program was introduced. Currently, the network consists of 7 regular program stations and 52 miscellaneous stations, of which the Peace River region accounts for 2 regular program and 9 miscellaneous stations. (Figure 2.2.1)

Today, a regular program station is one which has an observer who takes samples, more or less based on a flow-weighted sampling guideline designed and provided by the Calgary office. In addition, technicians take a sample whenever they visit the station. At a miscellaneous station, however, samples are only collected when the technician visits the site, i.e. either on a regular field trip or during an extreme storm event. At this time it should be pointed out that a "sample" consists of two pint-size bottles, labelled A and B, and at present only collected during the open water period. In the past, samples were collected at some of the stations on a year-round basis, but after studying the winter sampling periods, it was decided to discontinue the winter program because of low concentration values, the difficulty of obtaining samples and the problem of samples freezing.

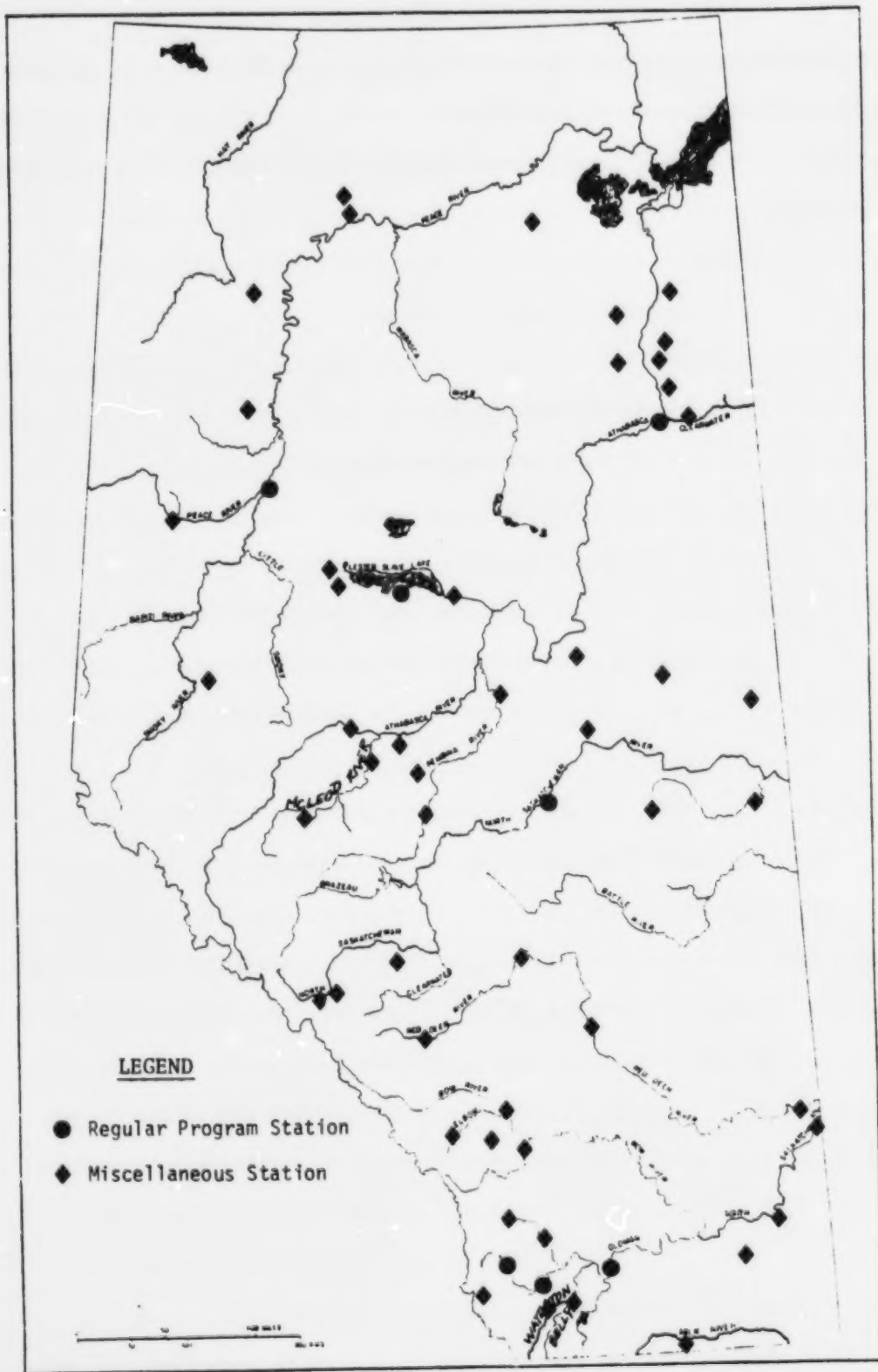


FIGURE 2.2.1 1988 ALBERTA SEDIMENT PROGRAM

The regular program station network has changed from about 25 in 1982 to 7 in the current year. This is partly due to stations being discontinued or converted to miscellaneous status based on any combination of the following reasons:

- (1) decreased financial support,
- (2) loss of the observer in a remote area without being able to find a replacement,
- (3) it was recommended in a station review report such as, "Sediment Station Analysis: Highwood River near the Mouth, 05BL024", that the station's status be changed (Day and Spitzer, 1985a).

Earlier it was mentioned that a sampling guideline is used for regular program stations. This guideline is based on the river discharge during the period of record for that hydrometric station. Typically, more samples are obtained during the spring time when the freshet (high water runoff) occurs, thereafter sampling tapers off during the summer and fall periods. However, during extreme storm events, more sampling is undertaken, especially for regular program stations where the additional samples help in interpolating and drawing the sediment concentration hydrograph.

During the past year, a new management tool has come into being, namely, the Station Management Plan (SMP). This is a comprehensive package designed to provide the sediment network manager with all the data on a station, from both the sediment and hydrometric perspectives, in order to help more efficiently plan the coming year's sampling program.

The Calgary office receives an average of 2 requests per month for sediment data, such as, sediment loads, publications or explanations of terms or procedures. Typically, most requests are from the consulting engineering community wanting to know peak or annual loads. One year, however, there was a request from a fisheries biologist seeking information about water temperatures in the Highwood River near High River. Since water temperature is routinely collected when a sample is taken, we are capable of supplying such information for sediment stations.

The Alberta district has published 6 sediment data analysis reports over the last 3 years, with another three areas currently being investigated. The reports are:

Highwood River near the Mouth (Day and Spitzer, 1985a)

Oldman River near Brocket (Day and Spitzer, 1985b)

Red Deer River Basin (Hydrocon, 1987)

Milk River Basin (Spitzer, 1987)

Sediment Source Study for the Oldman River

(Hudson and Askin, 1987)

K-factor Analysis Red Deer River at Drumheller (05CE001)

(Hydrocon, 1988)

Based on previous sediment station analyses of long-term data records, there are going to be fewer long term, i.e., greater than 10 years, regular program stations, and more of a trend towards miscellaneous-type stations. Another possible change to the program will be to focus more on the irrigation districts where negligible sediment data have been collected to date.

2.3 Data Collection and Processing (M.A. Cashman)

The Water Survey of Canada collects three basic types of data: suspended sediment, bed material and limited bed load, at 202 sites in Canada of which 71 are in Alberta (Environment Canada, 1988e). Historically, data have been collected at 164 sites in Alberta (Environment Canada, 1988f).

To collect suspended sediment two methods are used, depth-integrating and point-integrating. To collect a suspended sediment sample using the depth-integrating method, a sampler (Figure 2.3.1) is lowered at a constant rate, from the water surface to the streambed and returned at a constant rate, but not necessarily the same rate (Environment Canada, 1988e). In sampling suspended sediment various depth-integrating samplers are used: DH-48, DH-59, D-74 and D-77 being the most common (Cashman, 1988).

The most common samplers used for point-integrating are P-61, P-63 and P-72, while the PS-82 automatic pump sampler is used to collect samples at remote sites. To collect a point-integrating sample, the sampler is lowered to a pre-determined depth, the nozzle is opened to collect the water/sediment mixture and then is closed (Environment Canada, 1988e). A

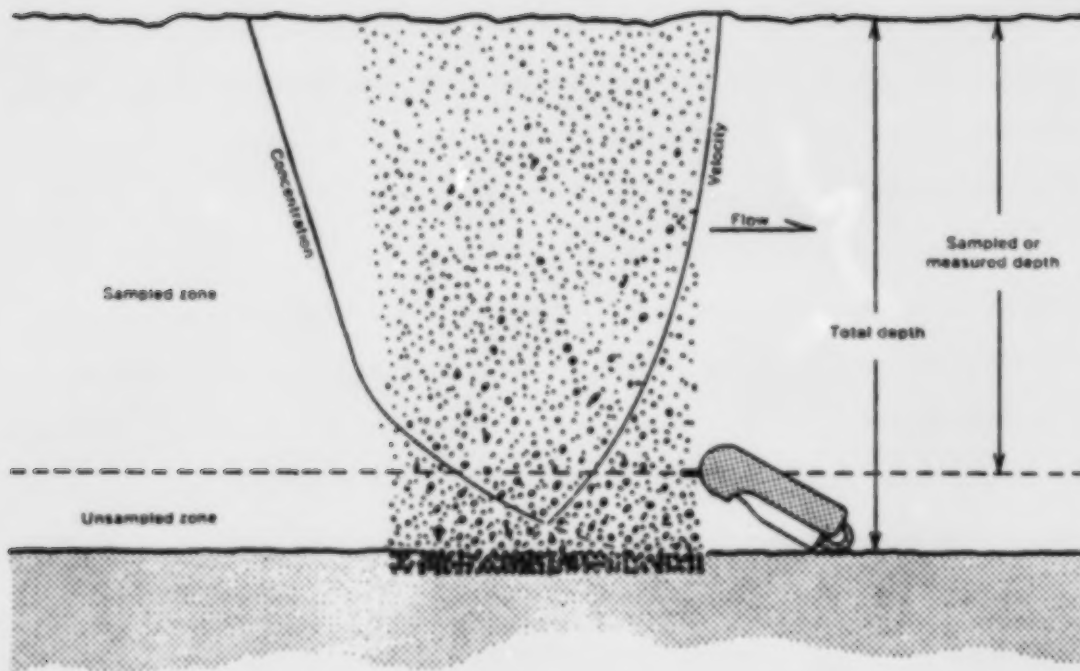


FIGURE 2.3.1 DEPTH-INTEGRATING SAMPLING

total of 400 point-integrating samples have been collected at one station (South Saskatchewan at HWY 41) in the province.

Although many types of bed-material samplers exist, the most frequently used are the BM-54, BMH-53, Scoop and the Canadian Drag Bucket (Lane) (Environment Canada, 1988b). Recently revised guidelines for sampling bed material in gravel beds (Yuzyk, 1986) and sand beds (Ashmore et al., 1988) have been prepared. Over 500 bed material samples have been collected at 24 sites in the Alberta since 1962.

Limited bed load information exists because of the difficulties involved in obtaining reliable bed load data. In fact, bed load data have only been collected at six sites in the province. Volumetric estimates are available for five sites, while sampling results using the VUV sampler exist for one site (Elbow River at Bragg Creek).

Suspended samples are treated with copper sulphate to control algae growth and are then sent to one of the laboratories for analysis. Two types of analysis are used to supply total concentration: evaporation and filtration (Environment Canada, 1988a). For the filtration method, we use an AP20 prefilter and a 934AH filter and oven dry the residue in a crucible at 105 °C for 3 hours. Particle-size distribution for suspended sediment samples is done by the bottom withdrawal tube method. Figure 2.3.2 presents the flow of sediment samples from sample collection to the laboratory analysis.

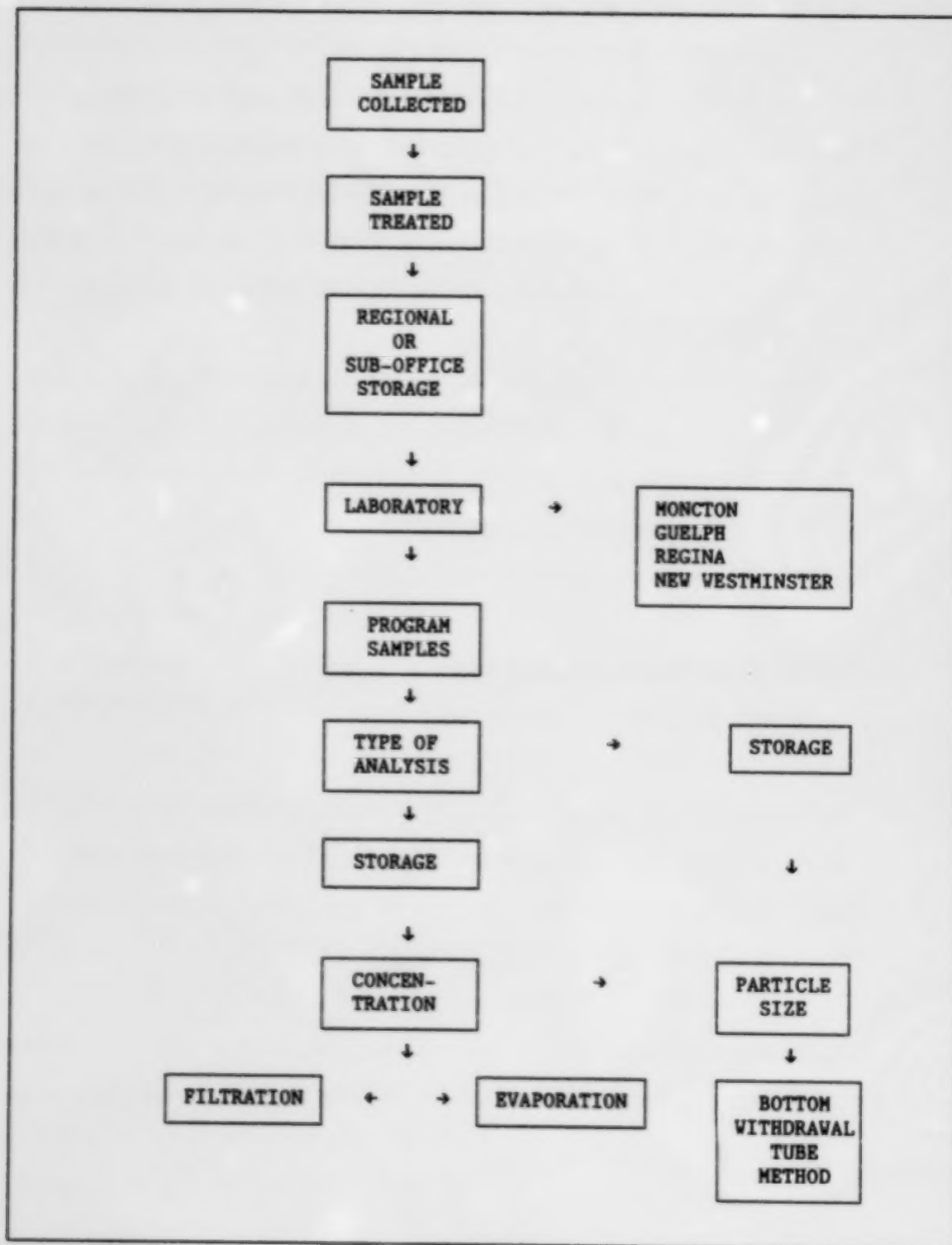


FIGURE 2.3.2 ANALYTICAL FLOW CHART, SUSPENDED SEDIMENT ANALYSIS

2.4 Laboratory Analysis (R.H. Yungvirth)

In 1961 the first sediment laboratory was established at Saskatoon by the Water Resources Branch of the Department of Northern Affairs & Natural Resources. Presently, three additional laboratories have been established and one relocated. These laboratories, providing operational support to regional water resource programs, are located in the following Regions:

- Pacific & Yukon Region at New Westminster, British Columbia
- Western & Northern Region at Regina, Saskatchewan (relocated from Saskatoon)
- Ontario Region at Guelph, Ontario
- Atlantic Region at Moncton, New Brunswick.

In the Quebec Region, federal sediment program support is provided by the other regions on an "as needed" basis.

The Regina laboratory is permanently staffed by three full time positions. These positions include two laboratory technicians and a technical supervisor reporting to the Data Control Supervisor at the Regina WRB District office.

The laboratory facility is a service and production oriented operation. The laboratory's main function is to perform routine physical analyses on

suspended and deposited sediment samples to determine concentration, dissolved solids and particle-size distribution data parameters (Environment, 1988a). An average of 5000 analyses are carried out by the laboratory each year. The prime responsibility of the sediment laboratory is to provide analytical support services to the sediment programs conducted by the Water Resources Branch within the Western and Northern Region of the Inland Waters Directorate.

Analytical services, on a minimal basis, are also provided on request to provincial government agencies and consultants. Services provided to users outside the laboratory's immediate responsibility centre are normally determined and reimbursed on the basis of a cost-recovery agreement.

Sample processing functions are conducted utilizing established international standard methods, in accordance with procedural guidelines for either of two analytical programs. The major analytical program, accounting for approximately ninety percent of the laboratory's analytical activity, involves the application of gravimetric methods of analysis to determine the following data parameters:

- i) the concentration (mg/L) of the suspended sediment of a sample by the filtration or evaporation method, and
- ii) the concentration (mg/L) of the dissolved solids of a sample by the evaporation method, or

iii) the particle-size (mm) distribution and classification of a sample by the bottom withdrawal tube method. This method also provides the concentration data parameters of suspended sediment and dissolved solids.

Program decisions in method selection are based in part on the limitations of the analytical concentrations required for particular methods. Analyses to determine the concentration of suspended sediment are normally carried out by the filtration method. The evaporation method is performed only on samples with apparent high silt/clay fractions, or when the concentration of suspended sediment in a sample would exceed approximately 2000 mg/L.

The determination of dissolved solids concentration data are subject to the program requirements established for each particular sediment station.

Particle-size analysis by the bottom withdrawal tube method is limited to samples with respective minimum and maximum dry sediment weights of 0.15 and 5.0 g. Maximum particle diameters, in samples analyzed by this method, are not to exceed 1.00 mm.

The second analytical program includes the analysis of deposited or bed material samples. This program involves the application of dry sieve and/or hydrometer methods of analysis to determine the particle-size distribution and classification of bed material samples. Program decisions in method selection are based on the analytical limitations imposed by the silt/clay fraction (particle diameters less than 62 micrometres) of a

sample. Samples indicating a silt/clay fraction greater than 10 percent of the total dry sample weight are analyzed by the hydrometer method.

Each labelled sample container is visually inspected and designated as to the type of data parameters to be determined and the method of analysis. Samples are then removed to a darkened storage area. This is a further precautionary step which is taken in addition to a copper sulfate treatment to inhibit the growth of algae. Suspended sediment samples are shelved for a minimum undisturbed period of one week to allow the sediment to completely settle from suspension.

As analytical scheduling permits, or when the sedimentation period has lapsed, samples are submitted to methods and procedures of analysis previously determined. The selection of samples for daily analyses are determined on the basis of program priorities and/or the period of storage.

Analytical data determined by the evaporation, filtration, hydrometer and dry sieve methods are manually computed and checked using a calculator. Particle-size distribution curves are manually plotted from data determined by the latter two methods. Data computations for the bottom withdrawal tube method are performed by computer program via terminal input to an in-house operating system. Data checking procedures for this method are carried out through internal program error messages and defaults and by cross-checking output with input data. The computed particle-size data parameters for this latter method are provided in tabular form on a hardcopy output listing. An optional plot of the particle-size distribution is available if graphical data are required by the user.

At present, two systems of compiling final analytical data are carried out by the laboratory. Data from a majority of the samples analyzed are compiled using a system whereby the determined data parameter results, for each particular station, are transferred in chronological order of sample collection to a working draft copy of a form entitled "Summary of Analysis Results". Pertinent corresponding sample collection information, from the original field survey notes received with the samples, is also transferred to this form. A duplicate version is typed from each draft copy as data entries are completed. Field survey information and analytical data for each sample on this typed version are verified by manually cross-checking with the original field survey notes, laboratory work forms, computer output listings and particle-size distribution plots.

Photocopies of these final verified summary of analysis results forms, including copies of curve plots and output listings for samples analyzed for particle-size distribution data are forwarded to the responsibility centre operating the particular sediment station.

With the second system, final data compilation is carried out on an extended version of the field survey notes form. This form includes an analytical data entry format to provide a summary of the sample analysis results with the original sample collection information. The determined data parameter results are transferred directly to the original field survey notes forms which are received with the samples. Analytical data entries for each sample are verified by manually cross-checking with the original laboratory work forms, computer output listings and particle-size distribution plots.

These combined original field survey notes and final verified summary of sample analysis results forms, including copies of the computer output listings and plots for field survey notes and final verified summary of sample analysis results forms are retained in a laboratory file.

The future of the laboratory is directed toward the following:

1) Automation.

- implementing an automated data management system.
- evaluating and acquiring an automatic particle-size analyzer.

2) Streamlining and improving existing analytical procedures.

3) Improving implementing quality control procedures.

4) Implementing additional methods and procedures.

- fixed, filterable and non-filterable residue.

2.5 Data Interpretation (T.R. Yuzyk)

Data interpretation is used to provide information such as demonstrated by the various reports prepared for the Sediment Survey Report Series (Cashman, 1987), or to help guide and ensure the proper management of the data collection program. This section focuses primarily on the latter application.

A Station Management and Information System (SMIS) has been developed for the sediment program. This particular system is comprised of four elements: profiles; station management plan; technical analyses and summaries; and, assessment and planning (Table 2.5.1).

TABLE 2.5.1 STATION MANAGEMENT AND INFORMATION SYSTEM (SMIS)

ELEMENT					PURPOSE
1) <u>PROFILES</u>	(A) HYDROMETRIC		(A) <u>INFORMATION</u>		
	(B) SEDIMENT		(B) <u>INFORMATION</u>		
2) <u>STATION MANAGEMENT PLAN (SMP)</u>	STATION #1	STATION #2	STATION #3	STATION #4	<u>EVALUATION PLANNING</u> <u>QUALITY CONTROL</u>
3) <u>TECHNICAL ANALYSES AND SUMMARIES</u>	(A) SINGLE STATION ANALYSES		(A) <u>ANALYSIS AND INTERPRETATION FOR DECISIONS AND SUMMARY</u>		
	(B) BASIN/RIVER SYSTEM ANALYSES		(B) <u>ANALYSIS AND INTERPRETATIONS FOR DECISIONS AND SUMMARY</u>		
4) <u>ASSESSMENT AND PLANNING</u>	NETWORK PLANS AND PROGRAM OVERVIEW				<u>OVERVIEW ASSESSMENTS AND PLANNING</u>

The first element in the system is the profile (hydrometric and sediment) which provide very general information on the station. The hydrometric and sediment profiles are similar in structure but provide different information. Table 2.5.2 outlines the individual components and the basic information that is contained within each. It is the intention of the Branch to prepare these profiles for all the active hydrometric stations and for both the active and discontinued sediment stations.

TABLE 2.5.2 STATION PROFILES

	<u>HYDROMETRIC</u>	<u>SEDIMENT</u>
	\\	/
HYDROLOGIC PERSPECTIVE	A) <u>SUMMARY OF CURRENT USES</u> - PURPOSE(S) OF STATION - MAIN DATA USERS	SEDIMENT PERSPECTIVE
	B) <u>STATION BACKGROUND</u> - HISTORY - MAJOR DEVELOPMENTS AND THEIR IMPACTS	
C) <u>HYDROLOGIC SUMMARY</u> - BASIN DESCRIPTION - HYDROLOGIC CONDITIONS - IMPACTS BECAUSE OF MAN		
D) <u>OPERATIONAL SUMMARY</u> - TYPE OF OPERATION - OPERATIONAL PROBLEMS		D) <u>PROGRAM SUMMARY</u> - RECORD LENGTH - EQUIPMENT AND PROCEDURES - SAMPLING STRATEGIES - SAMPLE COVERAGE
E) <u>ADDITIONAL DATA AND INFORMATION</u> - DATA PROCESSING CONCERNS - ADDITIONAL DATA (CROSS SECTIONS, PRECIPITATION, ETC.) - KEY REPORTS		

The Station Management Plan (SMP) was recently developed to provide a systematic approach to reviewing the data in order to assess if the station objectives are being addressed and determine when sufficient data have been collected. This system was developed to address "miscellaneous" stations where the strategy is to collect a limited number of samples on an annual basis. Under SMP, sufficient data are collected to derive a suspended sediment rating curve. The initial plans were completed, under contract, for all the active and discontinued stations in Alberta. This year marks the first year where the plans will be incorporated into the beginning of the planning cycle. The main components of the system are as follows:

TABLE 2.5.3 STATION MANAGEMENT PLAN (SMP)

- | | | |
|-----------------|---|---|
| PLOT
PACKAGE | { | 1. <u>GENERAL INFORMATION</u> |
| | | - STATION OBJECTIVES |
| | | - STATUS |
| | | - RECORD LENGTH |
| | | - DATA OUTPUTS |
| | | 2. <u>PLOTS</u> |
| | | - KEY PLOTS NEEDED FOR REVIEW KEPT WITH FILE
(I.E. CONC. VS. DISCHARGE, SAMPLE COVERAGE VS. FLOW DURATION) |
| | | 3. <u>TABLES</u> |
| | | - KEY TABLES NEEDED FOR REVIEW KEPT WITH FILE
(I.E. SAMPLE SUMMARY, PARTICLE SIZE DATA) |
| | | 4. <u>ANNUAL REVIEW</u> |
| | | A) CONCENTRATION COVERAGE |
| | | B) PARTICLE SIZE COVERAGE |
| | | C) BED MATERIAL SAMPLING PROGRAM |
| | | 5. <u>HISTORICAL REVIEW</u> |
| | | - BASICALLY SAME AS ANNUAL EXCEPT EXTREMES RECORDED |
| | | 6. <u>WORK PLANS</u> |
| | | - PROPOSED |
| | | - EVALUATION |

Once there appears that sufficient data have been collected (SMP input), then a major review is undertaken. The data findings and decisions regarding the operation of the station (continue or discontinue) are reported on.

In Alberta two station analyses have been completed:

- Highwood River near the Mouth (05BL024) - Day and Spitzer (1985a)
- Oldman River near Brocket (05AA024) - Day and Spitzer (1985b).

A draft report has been currently completed for the South Saskatchewan River at HWY 41 (05AK001) station.

The early reports were very voluminous as the appendices contained all the available data. Due to costs and the feeling that the large size of the reports was intimidating, resulted in a shift to shorter reports (Glavic et al., 1988) with only examples of the data outputs. Since the first station analysis, a standard for reviewing the data has emerged, especially where the station objectives are to characterize the sediment regime.

One of the major concerns with reviewing the data was trying to relate the findings to the basin. In most cases information on upland processes was very limited and land use changes were not well documented. To address this matter a pilot study was undertaken to identify sediment sources within the Oldman River basin (Hudson and Askin, 1987). The pilot work showed promise and the intentions of the Branch are to get more involved in similar studies.

The next level of evaluation requires linking information gathered from a number of stations along a river or within a drainage basin. This approach provides a more complete spatial picture of the sediment budget, which in turn can be used for a variety of environmental assessments.

In Alberta a few basin analyses have been completed:

- Milk River Basin (7 Stations) - Spitzer (1987)
- Red Deer River Basin (3 stations) - Hydrocon (1987)
- Saskatchewan River Basin (112 stations) - Ashmore (1986).

Currently, two other basins are being studied: Lesser Slave Lake and the lower Athabasca River.

A couple of major reviews relating to the prairies were undertaken in recent years. The first dealt primarily with identifying sediment issues and made general recommendations on how the sediment program could be more effective (NHCL, 1985). A second review (Day, 1986) followed which focused more on providing specific details on program direction over a 5-year period (1985-1990).

This particular workshop is one of the strategies which were identified in both of these reviews. Another strategy was to emphasize information rather than data. The variety of software products and interpretive reports have been the results. Currently, the program has contracted the Alberta Research Council to produce a document entitled, "Regional Sediment

Characteristics for Alberta" in a continuing effort to focus on the value of the network to address the variety of engineering and environmental needs.

2.6 Sediment Program Outputs (M.A. Cashman)

The suspended sediment samples, after laboratory analysis, are returned to the technical staff for final review. The data are interpreted and keypunched for eventual publication in the data books (Environment Canada, 1988e). The sediment data are published annually with Canada divided into eight regional data books. Each province represents a separate region except for New Brunswick, Newfoundland, Nova Scotia and Prince Edward Island, which together form the Atlantic provinces region and the Yukon and Northwest Territories which make up another. These annual data books contain data on active stations, some descriptive information on each site, tonnes listings, instantaneous data on depth-and point-integrating sampling, bed material and bed load. A historical summary and a brief statistical summary is also included, but only on active stations.

In addition to the annual data books, a Reference Index (Environment Canada, 1988f) is published every two years. This index includes descriptive information on each station, the type of operation and type of data available. It also includes the number of samples collected for each data type.

Recently a miscellaneous data publication (Environment Canada, 1988d) was released which includes data for 921 miscellaneous stations across Canada

for the period 1966 to 1983. This book is a one time publication and contains only instantaneous data.

Instantaneous data and tonnes are available on magnetic tape, computer printout hard copy and on floppy disk. The Branch is currently exploring the possibilities of supplying data to users on compact disk. Data prior to 1984 are available on microfiche, but funds have not been available to continue this production.

A "Field Sampling Manual" has been started and a "Sediment Equipment Catalogue" should be available soon for circulation. In 1984 the sediment program began publishing a report series and to date 68 reports have been printed. These reports pertain to sediment issues, stations analysis, studies, equipment, data indexes and statistical summaries. For information on these reports refer to Cashman (1987).

3. TECHNICAL SESSION

3.1 Fluvial Sediment-Contaminant Cycling: An Overview (H.R. Hudson)

In Canada, water quality assessment has traditionally been separated into two components - sediment related quality issues and contaminant related issues. This division possibly stems from the perception of sediment as an engineering problem and contaminants as a health issue.

Examinations of sediment as a water quality parameter focused mainly on physical and aesthetic damage to water quality. Agriculture and engineering interests concerned the deterioration of land surface quality, and quantity or sediment deposition affecting specific land and water uses. The fundamental suspended sediment attributes of concern were sediment quantity, size distribution of material, and perhaps the timing of sediment transport as it impacted particularly fisheries, municipal water quality and engineering structures.

A major concern of water management has traditionally been the maintenance of water quality, specifically, the avoidance of degradation that may be hazardous to health. Initially, much of the effort in preserving water quality was devoted to keeping bacterial counts down so that infectious diseases transmission was stopped (Siever and Stem, 1982).

Up to this point it was often adequate to view contamination of water supplies in a relatively simplistic fashion. The water column itself was considered to be the prime phase, or mode, of contaminant transfer. In

essence, a fundamental tenet of water quality assessment was that contaminant transfer could be viewed as a water routing problem with some chemical decay and dilution. However, there has been a change in both the nature and quantity of contaminant inputs, as well as in the source of contaminants, that suggests a review of this perception is warranted.

The introduction of new substances necessitates viewing the fluvial environment as an interacting medium rather than the traditional view of the fluvial environment acting as an inert or passive conduit through which contaminated water is routed. In the following section the nature of this interaction is described for contemporary contaminants.

3.1.1 Contemporary Contaminant Problems

3.1.1.1 Types and Sources of Contaminants

Contaminants may be simply defined as substances which are deemed to be undesirable (Blachford and Day, 1988). Some contaminants are derived naturally from atmospheric deposition, and surface and subsurface erosion of the earth's crust. Land use changes, such as increased agriculture, deforestation and mining, may modify runoff pathways and accelerate sediment yield and contaminant cycling of naturally occurring substances.

With increasing urbanization and industrialization, the nature and quantity of contaminant cycling has changed. Now, more contaminants are composed of effluents of modern industrial societies (synthetic chemicals, mining products, phosphates, metals, and by-products of energy production and consumption) (Siever and Stumm, 1982).

Major anthropogenic sources of contaminants include urban drainage, and agricultural fertilizers and pesticides, in addition to human excreta and gross industrial wastes. As well, the burning of fossil fuels, and the use of aerosols etc., widely disperse a variety of gaseous oxides, compounds of heavy metals, and solid particles.

In essence, the problem has evolved from that of point source contributions of infectious substances to include a wide variety of dispersed (or 'diffuse') contributions of contaminants.

3.1.1.2 Sediment Contaminant Interactions

Fluvial sediments are capable of transporting quantities of nutrients and contaminants to and within the aquatic systems, and of regulating nutrient and contaminant availability to the biological community. The degree of interaction is highly dependent on sediment characteristics and ambient stream parameters.

Clay minerals, clay-rich aggregates, and heavy minerals, are the major carriers of toxic metals in suspended loads, but the major accumulative phases in specific environments are Fe/Mn oxides, carbonates and sulphides. The main factors affecting the attraction of toxic organic chemicals to sediment particles are the solubility of the substance, concentration of the substance, concentration of the sediment, type of sediment (particularly organic content or degree of lipid layering), time, concentration of other chemicals and ions in solution, and temperature (Allan, 1986).

The importance of suspended sediment was demonstrated by Blachford and Ongley (1984) who examined biogeochemical pathways of phosphorous, heavy metals and organochloride residues in the Bow and Oldman rivers, Alberta. They demonstrated the importance of suspended sediment concentrations to water chemistry during high-water periods. For all metals, with the exception of mercury, the sediment-associated load comprised most, if not virtually all, of the total load in water.

They also noted that pesticides and PCB residues characteristically have low solubility and high adsorptivity, and are persistent. Adsorption of organochloride residues onto solids is a common mechanism by which they are removed from the aquatic medium and transported in the fluvial environment. The pesticide DDT, dieldrin and PCBs are known to be absorbed from aqueous solutions by particulate matter in direct relation to the organic content of the material.

As was the case for many of the metals in the Bow and Oldman rivers, pesticides, PCBs and organochloride residues exhibit distinct seasonal trends. Blachford and Ongley (1984) found that greater amounts of sediment-associated residues occur in the summer and fall (when suspended material has greater amounts of organic) than in the spring (when the suspended sediment load was dominated by mineral sediment).

The challenge for the future is that we do not know which of the thousands of conceivable substances will be introduced into the fluvial environment. It does not appear to be realistic to study the detailed geochemical behaviour of all of the potentially harmful substances. As it is, there

are few unambiguous criteria for the concentrations in natural waters that produce toxic reactions or are mutagenic, teratogenic, or carcinogenic (Siever and Stumm, 1982).

The Environmental Protection Agency (EPA) list of priority pollutants shows that the majority of target compounds are highly related to instream sediment. The contaminants may be tagged to the sediment at source (for example in the erosion of herbicides and pesticides from agriculture lands and from airborne contaminants such as Cesium¹³⁷) or the sediments may attract these contaminants from the water column.

Chapman et al. (1982) evaluated the EPA list of priority pollutants and recommended which phase (the water column, suspended sediment or stream biota) should be sampled based on the anticipated fates and effects of the compounds. Although some contaminants are significant in each phase, sediment is the recommended sampling medium for 67 percent of these chemical compounds, biota for 50 percent, and water for 34 percent.

A large number of contaminants are preferentially associated with sediments. Once these contaminants are absorbed or attached to the sediment, the pathways and fate of the contaminant are determined by the hydrologic and sediment regimes. Understanding pollutant transport, fate and effects in the aquatic environment therefore clearly necessitates understanding facets of the suspended sediment regime.

3.1.1.3 Biotic Contaminant Interactions

As discussed previously, half of the Environmental Protection Agency (EPA) list of priority pollutants are very strongly associated with stream biota. Chemical loadings in biomass are often very much greater than loadings in transit in the water column. For example, Blachford and Ongley (1984) found that the biomass phosphorous load of the Bow River below Calgary is up to two orders of magnitude higher than that measured as chemical flux in the water column. They suggest that these loadings represent a substantial component of the bioavailable fraction which might reasonably be expected to be monitored in the water phase if there was no biomass.

Significant plant uptake implies a major loading which is temporarily stored in biomass. Thus, the potential for loading downstream sedimentary environments, such as deltas, with degradable organic debris and consequent release of metals could be significant.

In addition, sediment dwelling worms and other organisms mine the sediment for their food and may reintroduce some substances back into the water. Biological disturbance (bioturbation) may revork surficial sediments such that the time required to bury contaminants is prolonged. Also, fish may accumulate chemicals by direct desorption from or ingestion of contaminants (Siever and Stumm, 1982; Allan, 1986).

It is clearly apparent that the biotic regime is a fundamental component of the contaminant regime.

3.1.2 Implications for Water Quality Assessment

The fluvial system can no longer be considered an inert conduit between contaminant sources and sinks. The disposition of contaminants in the fluvial system is determined by the interaction of the chemical cycle, biological cycle and the sediment - hydrodynamics cycle. The interaction of these cycles determines the transfer and storage mechanisms, or phase, and routing of the contaminants.

For many present and projected contaminants, the predominant transport and storage phase is either sediment associated or stream biota associated. Hence, it is apparent that it is no longer adequate to monitor the water column alone to assess water quality. Determination of contaminants associated with biota and sediments must become routine in water quality assessment along with continued water column measurements.

The need to monitor the sediment and biotic phases in addition to the water phase in water quality assessment will not be without difficulty. However, because many persistent, toxic, organic chemicals have already been bioaccumulated (or geoaccumulated) to significant levels, it is possible to detect contaminants in the biotic and sediment phase before it is analytically possible to measure them in the water phase (Allan, 1984). Further, as Blachford and Ongley (1984) and Ongley et al. (1985) point out, such sampling also permits chemical characterization of bioavailability and inferences concerning source.

In terms of sediment, it is no longer adequate to describe instantaneous sediment concentrations and sediment-size distributions on a miscellaneous basis. Water quality assessment will require specific information on sediment quality, and sediment regime (concentration and quality variations with time) as well as information of sediment sources and sediment routing. Sediment quality refers to size and composition of sediments including differentiation of biological particles, inorganic particles, and humic substance (Witkowski et al., 1987).

3.1.3 Workshop Presentations

The three main elements to the water quality conundrum involve the chemical cycle, biotic cycle and sediment-hydrodynamic cycle. This workshop seeks to elucidate the role and complexities of each of these elements.

This, the introduction, presents the overall picture as to how the cycles are related and why stream biota and sediment are important aspects of water quality assessment.

Physical processes of sedimentation are then discussed to illustrate how and why sediment moves from upland areas into, and through, the fluvial system. Specific topics include:

- processes determining the derivation of sediment from upland areas;

- how upland areas and rivers interact in terms of sediment sources, pathways and sinks; and
- engineering aspects of sediment including how the existing sediment data base can be used to quantify sediment loads and particle-size distributions, and how the data base can be interpreted to deduce sediment sources and processes.

The second series of presentations address chemical and biological aspects of water quality assessment. Specifically:

- the discussion on sediment in water quality assessment examines data availability and the role of sediment in the aquatic ecosystem; and
- the presentation on sediment impacts on fisheries examines the necessity for treatment of specific industrial effluents and the data requirements for assessing environmental impacts.

Finally, conclusions will be drawn regarding implications for water quality assessment.

3.1.4 Conclusions

It is apparent that, in water quality assessment, the fluvial system must be viewed as a dynamic, rather than inert, conduit of contaminants, water and sediments from uplands through the river system.

The critical elements identified in the water quality assessment conundrum include chemical cycling, biotic cycling and sediment - hydrodynamic cycling. In their own right these cycles are difficult to understand quantitatively. The challenge for the future will be the development of an understanding of these cycles as they interact in the fluvial environment so that more informed water quality objectives can be developed and implemented.

3.2 Erosion from Upland Sources (R.W. Howitt)

The purpose of this paper is to discuss erosion on uplands, and the relationship between erosion and the sediment in rivers and lakes. The terms uplands will be interpreted loosely as any area of the landscape not occupied by a river, stream or lake. Erosion is the detachment, transport and deposition of earth material. Erosion is highly variable in time and space and it is necessary to consider the scale of erosion when discussing the phenomenon.

3.2.1 Processes of Soil Erosion

Soil erosion is generally divided into two categories: wind and water erosion. These categories can be further subdivided based on the nature and scale of the process.

Wind erosion is generally thought of as being composed of two processes, saltation and aflation. Saltation is the physical bouncing of particles along the ground surface and tends to influence mostly heavier materials,

such as sand and silt. Aflation occurs when particles are lifted from the soil surface into suspension by the wind. Aflation affects lighter materials, such as organic matter and silts, and to some degree soil aggregates. The role of windborne sediment in the fluvial sediment regime has not been quantified but secondary evidence suggests that the contribution is often relatively small even from agricultural land in windy areas, such as the Cardston Plain in southwestern Alberta (Hudson and Askin, 1987). Water erosion, on the other hand, can deliver considerable amounts of sediment directly to water bodies due to runoff.

Upland water erosion is divided into three processes: rill, interrill and gully erosion. Rill erosion is caused by concentrated flow of water over the landscape and results in the formation of small channels called rills. Rills tend to be on the order of 0.1 m deep, 0.2 to 3.0 m wide and up to several 100 m in length. On agriculture landscapes, rill erosion is often masked because conventional cultivation techniques eradicate them.

Interrill erosion is the movement of soil between the rills and does not generally result in observable features on the land surface. Interrill erosion occurs on a scale of 0.05 m to 10 m in length. Rills grade into gullies. Gullies can be 10's of metres in depth and width, several 100 m long and often form an impediment to cultivation. Gullies grade into stream channels. This process can result in very significant contributions of sediment to the rivers and streams (e.g. upper Oldman River, Hudson and Askin, 1987; Bow River basin, Luk, 1975).

Deposition is a process that is inherent to erosion, but is often ignored or not considered in upland soil erosion studies. Deposition also occurs at a

variety of scales. Continental denudation results from the removal of upland sediments by rivers. The ultimate depository of sediment are the ocean floors. On a more regional scale, lakes and other water bodies in the province can serve as depositional environments for sediment eroded from the upland. Finally, on the upland itself there are numerous areas characterized by deposition resulting from rill and interrill erosion. Very little attention has been paid to these areas in the literature pertaining to upland soil erosion. These areas of deposition impede the movement of eroded soil from the upland into rivers and streams.

3.2.2 Approaches to Measuring Soil Erosion

A variety of techniques have been employed to measure or estimate soil erosion on upland areas. Plot studies are by far the most common technique for measuring erosion. In Alberta, Toogood (1963) and Chanasyk and Wotowich (1983) used standard sized Wischmeier plots to estimate water erosion in the Edmonton and Peace River regions, respectively. Luk (1975) used a modified plot design to evaluate soil erosion in the Bow River basin. Plot studies are excellent for evaluating different treatments, such as cropping practice on soil yield, but do not separate the erosional processes (rill and interrill erosion). In addition, plot studies do not give any indication of the fate of the eroded material.

The Universal Soil Loss Equation (USLE) was developed from plot studies that took place throughout the United States. The USLE is the most commonly used estimator of upland soil erosion. It is based on the evaluation of 6 factors (Rainfall, soil erodibility K, Slope gradient, slope Length,

Cropping practice, and erosion control Practice). However, the applicability of the USLE is limited in Alberta. To date, there is no satisfactory method of including snowmelt processes or frozen ground conditions in an equation, yet most of the annual erosion and transport occurs during spring in Alberta.

The USLE is usually applied at a plot scale to derive estimates of average annual soil erosion. The equation has also been applied at a drainage basin scale. It must be noted that such applications generally ignore the partial area concept of sediment source areas as presented by Campbell (1985).

Recent studies by Howitt (1987) in East-Central Alberta have attempted to measure upland erosion and deposition processes. Soil erosion pans similar to those employed by Roels and Jonker (1983) were used to estimate the relative contribution of interrill erosion in an agricultural field. The rill meter, as described by McCool et al. (1981), was used to measure the amount of rill erosion. Areas of deposition were identified and mapped in the basin based on rill patterns and soil properties. This approach to measuring soil erosion attempts to measure the processes of erosion and has value in identifying sediment source areas and depositional areas in the landscape.

3.2.3 Upland Erosion and the Sediment Cycle

It is clear from sediment yield studies that the amount of sediment in most rivers is substantially less than would be predicted using the USLE and the area of the drainage basin. There have been very few studies which attempt

to link upland erosion and the sediment content of rivers and lakes. Hudson (1983) found that the major sources of suspended sediment in the Elbow River basin, in southwestern Alberta, were from channel and riparian erosion. The contribution from upland erosion in the forested upper basin and in the lower, agriculturally developed plains was found to be small. Similar results were reported by Hudson and Askin (1987) in the upper Oldman River basin. It was also found that significant sediment was derived from localized gully erosion. Luk (1975) reported similar results in the Bow River basin.

Martz and Campbell (1980) reported on the relative contribution of pipeline development on the sediment load in the Spring Creek watershed in the Peace River region of Alberta. The installation of a pipeline resulted in a 36% increase in watershed sediment yield over 4 months. Rill erosion was reported on the upland area of the pipeline development but this process had little influence on the overall sediment yield increase. Rather, slope failure was reported to be the dominant process in sediment delivery to the stream.

Hovitt (1986) found that all of the soil material eroded by water in a small agricultural field was subsequently redeposited within the field. Areas of deposition in the basin had very thick depositional horizons characterized by buried Ap horizons (plow layer), separated by layers of sedimentation characterized by cross bedded sand and organic matter. In order for this basin to contribute to regional sediment yield, the water level in the slough at the bottom of the basin would have to be two to three metres higher than current levels. Martz (pers. comm.) reported considerable

redeposition of soil in a research basin in Saskatchewan and noted that a very intense storm would be necessary to dislodge the deposited material.

The upland is composed of a considerable number of sources and sinks for erosion and deposition. This can be demonstrated by considering the very thick Ah horizons developing in lower slope positions and depressions in the landscape. Further, an integrated and efficient drainage network is often not present to move material from eroding fields to the river. Hudson (1983) reported that in the lower reaches of the Elbow River, sediment delivery from agricultural fields to the river was impeded by an inefficient drainage network.

In conclusion, the link between upland erosion and the sediment in Alberta rivers and lakes is not well defined. Current work suggests that the majority of sediment in rivers is the result of erosion in the channel or very close to the channel. Continued effort is required to clarify the relationship between upland erosion and sediment yield. The partial area concept of sediment source areas should provide a foundation for continued work.

3.3 Instream Sediment Transport (I.A. Campbell)

The fluvial system is a physical system with a history and the geomorphologist has not only to understand the physics and chemistry of the river but its alteration and evolution through time (Schumm, 1977). Studies of instream sediment transport require an understanding of the fact that river channels, when viewed instantaneously or on a short time scale, often

give appearances of conditions which may be far removed from their long term state. Discontinuities are common and periodic arrangement of instream sediment is an expected phenomenon.

Geomorphic interest in sediment transport lies in its effects on channel morphology. This can be seen in terms of a process-response model the basis of which is a continuity equation; if differences in input and output occur along a section of channel the change in storage must have morphological effects.

The fluvial continuity equation:

$$Q = A_1 \bar{v}_1 = A_2 \bar{v}_2 \dots A_n \bar{v}_n = \text{a constant}$$

defines fluid flow through a length of channel. When Q is constant this applies even though velocity varies. At any moment along a channel section, Q does not vary markedly despite often wide variations in A .

A sediment transport equation for the same length of channel would likely show enormous variations. The reason for this is that rivers are poly-phase transporters of water and sediment (Crickmay, 1974). The rate of the fluid flow never varies far from a mean velocity of 1 m/s while instream sediment transport rates vary enormously. Solute load moves at the same velocity as the fluid. But suspended, saltating, or bedload

velocities may be several orders of magnitude slower. The mean velocity of the total instream sediment transport may be barely perceptible. The reasons for this have not only to do with stream power (capacity and competence) but are also related to channel flow through cohesive or non-cohesive materials and the fact that availability of sediment for instream transport varies spatially and through time and as a function of location within the drainage network (Figure 3.3.1).

Channel systems have enormous storage capacities for sediment in transit from the source area to the ultimate accumulation site (the erosion-deposition-stability or EDS cycle). The rate of instream sediment transport reflects the sum total of channel processes and indications are that this rate is often significantly less than 25% of the rate at which sediment is derived from the land surface (ASCE, 1975). Thus, the majority of instream sediment is stored in floodplains, fans, bars, deltas, pools, lakes and behind and in manmade structures (Figure 3.3.2). Trimble (1981) showed that only about 6% of the sediment eroded from the 360 km² Coon Creek basin, Wisconsin, between 1853-1938 was removed from the basin. About 90% of the 25 km³ of soil eroded from the southern Piedmont in the last 200 years is still in valley storage (Trimble, 1975). Instream sediment storage times vary from micro-seconds to millennia.

For any model of instream sediment transport to accurately reflect these enormously varying time scales requires the construction of a stream sediment budget. According to Lehre (1982) this should incorporate:

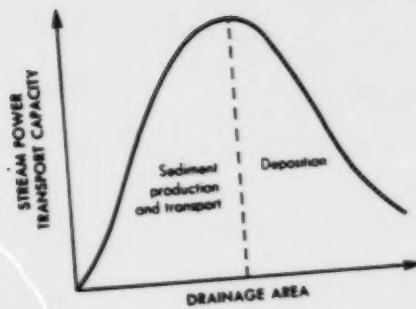


Figure 3.3.1 Generalized Relationship Between Stream Power/Transport Capacity and Drainage Area (after Graf, 1982).

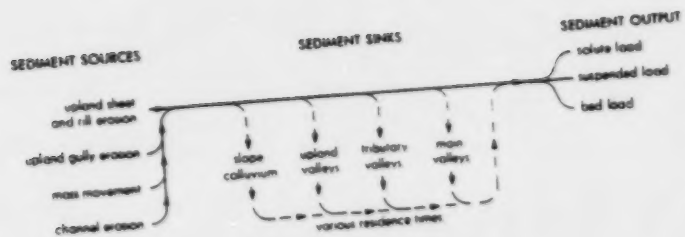


Figure 3.3.2 Flow Chart for Sediment Routing Linking Sources, Sinks and Outputs.

1. identification of transport processes and storage sites and understanding of their interrelationships and controls;
2. quantifying the contribution from each erosion process;
3. setting up a balance sheet showing production, sediment transport and storage changes.

How well this budget characterizes and quantifies the sediment conveyer system depends on how well transfers, storages and linkages in the system are understood, the precision and duration of measurements and the scale and temporal segmentation of the channel system (Swanson et al., 1982). Such approaches have rarely been used collectively and, in general, understanding of these processes is poor; interpretation methods are rudimentary and techniques are unsophisticated (Campbell, 1985). There is a pressing need to know more about residence times, recurrence intervals or reactivation phases of stored instream sediment (Figure 3.3.2) in addition to the quantities of sediment being moved (Meade, 1982).

3.3.1 Alberta Examples

In contrast to many alluvial-filled valleys in the central and western USA for which detailed, dated stratigraphic analysis has been done, comparatively little is known about instream sedimentation rates and sequences in western Canada. Likewise, the network of reliable, long-term stream sediment gauging stations is sparse, especially on the major northern rivers. Nevertheless, a considerable number of both general and highly detailed studies have used sediment data collected through federal or provincial agencies or independently researched basins. These studies

group into four broad categories; examples from each are used for discussion purposes.

1. Regional or provincial scale studies. These may involve Alberta rivers as part of Canada wide reviews or may concentrate largely on Alberta examples. Such studies are often highly generalized and are based on existing sediment records.
2. Detailed examination of sediment transport patterns in large basins largely or entirely in Alberta. Such studies frequently examine suspended sediment and stream discharge relationships.
3. Instrumental experimental catchment studies. These usually involve small or very small basins and may be based on only a few years of record or even a small number of isolated events.
4. Site-specific studies often focused on at-a-station sediment-discharge relationships or particular problem-oriented case studies. These often include engineering consulting reports and in-house government agency studies.

Of key concern is the relationship between the measured instream sediment load either at a point, or over some stretch of channel, and the source area of the sediment and the local mobilizing factors. Variations within this relationship are wide at both large and small scales.

Stichling's (1973) regional study of Canadian sediment yield patterns shows a more than 20 fold variation of suspended sediment concentration in Alberta rivers. Over most of the plains, concentrations are well below 700 mg/L with many basins showing <200 mg/L. The Red Deer stands out as a notable exception recording values in excess of 1000 mg/L. The Red Deer's anomalous condition results from an extensive area of badlands, about 800 km², along the lower reaches of the river. The watershed upstream of Red Deer consists mainly of foothills and mountains. It accounts for only 25% of the area of the basin, contributes 75% of the runoff and less than 10% of the suspended sediment load. The badlands, which form only 2% of the basin contribute about 90% of the 6 million tonnes annual average sediment load of the river (Campbell, 1977). This massive injection of sediment appears responsible for a marked hump in the river's profile through the badland section. This may represent long term storage of sediment which the river is usually incapable of moving.

Abrahams and Kellerhals (1973) used multiple linear regression analysis to examine relationships between discharge and suspended sediment concentration in four large prairie rivers including the Red Deer. Noting that their model generally produced reasonable results they found, with the Red Deer, that the rate at which sediment is injected into the river in the immediate vicinity of the channel, is independent of discharge and that most of this sediment is moved out on the rising stage. Kellerhals et al. (1974) found rating curves for the Red Deer gave constantly large errors, underestimating the recurrence of high sediment concentrations.

For streams like the Red Deer, where large sources of sediment are found in close proximity to the channel, the potential predicting error for sediment rating curves is large as the input of sediment is frequently unaccompanied by similarly high main stream discharge. More recently, Ashmore (1986) and Ashmore and Day (1988) examined suspended sediment transport in the Saskatchewan River basin. In a detailed sediment budget, Ashmore (1986) points out the importance of valley side and flood plain contributions. The duration of effective discharge (Ashmore and Day, 1988) within the Saskatchewan system varied from less than 0.1% to over 15% in a sample of basins from 10 to over 100 000 km². Small foothills and headwater basins tend to be dominated by extreme events in which the bulk of the channel sediment is moved in a few days. Large prairie rivers have longer duration effective discharges, often greater than 10%.

McPherson (1975) examined suspended sediment loads in 36 intermediate-sized basins in the plains, mountains and foothills. Basins ranged in size from 77 to 1430 km². He found no relationship between sediment yield and 'sediment contributing areas' (defined as total basin area minus areas upstream of lakes or dams); strong positive relationships were found with elevation, relief, slope and discharge. However the effective sediment contributing area is considerably smaller than the area defined above.

The major source of suspended sediment in the Upper Oldman is from lateral river erosion, slope wash and mass movements adjacent to channels (Hudson and Askin, 1987). They emphasize, as has been stressed by Campbell (1985), that yields of sediment do not represent basin wide averages and that a more realistic measure would be yield per unit distance of channel -

recognizing that not all channel segments are bordered by active sediment contributing sites. This is observed by Ashmore (1986), who notes that the effective area for water yield is much greater than the potential sediment producing area.

3.3.2 Summary

Stream discharge and suspended sediment discharge are related but form two quite distinct components of the fluvial system. They often differ markedly in their source areas and movement patterns, both rates and quantities. The relationships between the various phases of instream sediment transport (Figure 3.3.3) shows that at any particular location along a channel quite different 'sediments' may be in motion. Some of these may represent material already moving; others may have been mobilized after lengthy periods of storage. Without an accurate idea of these differences, attempts to relate discharge conditions with suspended sediment movements, even assuming the measurement procedures are accurate, can produce very misleading impressions of the manner in which sediment is derived, its source and its relationship to stream flow (Neill, 1987).



Figure 3.3.3 Instream Sediment Relationships Showing Inputs, Storage and Outputs.

3.4. Uses of Sediment Data in Engineering Projects (G.R.E. Beckstead)

The suspended sediment and bed material data gathered by the Water Survey of Canada (WSC) have been gathered virtually exclusively for engineering use. What are the engineering uses of these data? The following summary will first discuss engineering uses of sediment data in general. It will be followed by a presentation of several engineering projects in Alberta in which sediment data have played a significant role. Sediment yield in Alberta will also be discussed.

3.4.1. ENGINEERING USES OF SEDIMENT DATA

The general uses of sediment data in engineering projects are presented in Table 3.4.1.

TABLE 3.4.1 USES OF SEDIMENT DATA IN ENGINEERING PROJECTS

TYPE OF PROJECT	DATA NEEDS		PURPOSE OF DATA	
	SUSPENDED	BEDLOAD	DESIGN	REGULATORY
Reservoirs	*	*	*	
Water Intakes	*	*	*	
Diversions	*	*	*	
Sediment Ponds	*	*	*	*
Pipelines	*	*	*	*

3.4.1.1 Reservoir Studies

One of the most extensive uses of sediment data is for reservoir studies. Here the primary goal is to establish the magnitude of reservoir storage capacity lost through deposition of sediment. To do this, the incoming sediment load (tonnes) must be established, either from direct measurements on the stream or streams entering the reservoir or from estimates of sediment yield from the upstream catchment(s). The nature or size distribution of the incoming sediment load is also important. Knowledge of the relative percentages of sand, silt and clay is required to compute the ultimate density of the deposited sediment. It will also aid in forecasting the type and extent of the delta deposits. In cases where the incoming wash load (silt and clay) is significant, and where the reservoir has limited capacity relative to the incoming stream flow, a portion of the sediment load may pass through the reservoir and reduce the potential for stream bed degradation downstream of the dam. This is different from most situations, where the sediment load immediately downstream of dams is assumed to be zero.

3.4.1.2 Water Intakes

Sediment data are also an important consideration for water intakes. Bedload may clog the inlet works, necessitating occasional cleanout, or in extreme cases the construction of desilting works. Suspended load must also be considered, as the wear on pump impellers or on turbines and penstocks at hydropower installations may be significant. Timing of high

sediment loads relative to the withdrawal of water at an intake may also be an important consideration.

3.4.1.3 Sedimentation Ponds

The design and operation of sedimentation ponds are another use of sediment data. Here the suspended sediment data are of greatest significance as the magnitude of the load and the size distribution must be characterized to effectively determine the required pond dimensions. Total load data are also required to account for losses in storage which may affect long-term performance of the ponds, and its ability to meet downstream concentration criteria required by regulatory agencies.

3.4.1.4 Channel Diversions

Channel diversions must be designed to carry not only the required water flow but also the accompanying total sediment load. Sediment data may also be beneficial in establishing the potential impacts of diversions.

3.4.1.5 Pipeline Crossings

While not normally required in Alberta, regulatory agencies in other jurisdictions may require that sediment data be gathered and used to establish the effects of bed and bank excavation at pipeline stream crossings on downstream suspended sediment levels. In certain cases on large streams with appreciable bedload, filling in of the pipeline trench during pipe installation may also be a concern.

3.4.1.6 Other Engineering Uses

Campbell (1975) discusses other uses of sediment concentration, particle size and load data:

- * Since sediment information is a very good indicator of the undesirable consequences of development in a basin, background or pre-development data are often required so that comparisons can be made of conditions before, during and after development.
- * Sediment data may be used to assess the disposition of sediment when natural stream conditions are altered:
 - water diverted into canals could damage or silt up canals and damage crop land,
 - dyking prevents bank overflow, but may cause new downstream problems because the sediment that would have settled out on the flooded lands will eventually be deposited in the channel downstream, increasing the risk of bank overflow at that location. In some severe cases the stream bed has been raised in this manner and artificially contained within dykes well above the elevation of surrounding land, creating a potentially disastrous situation, (e.g. lower Mississippi River, U.S.A. or Brahmaputra River, Bangladesh).

- Where upstream dams reduce flood peaks, the sediment flushing action downstream may be reduced. This could cause a gradual buildup of stream beds, thereby increasing potential flood hazards, and completing a vicious circle.

3.4.2 Sediment Yield

One of the most common problems encountered by engineers in using sediment data is to estimate sediment loads for locations on streams for which no measured data exists. The procedure often used is to examine the sediment yield (tonnes/km²) of nearby catchments, and establish a pro-rated yield value for the basin by considering sediment source characteristics of the area. Figure 3.4.1 shows sediment yield data for sites around the world (Mahmood, 1987) with Alberta data added for comparison. One thing readily apparent from Figure 3.4.1 is that sediment yields in Alberta are substantially less than for other basins in the world with similar drainage areas.

Another important aspect is that there is a considerable degree of scatter in the plot, which may be due in part to variances in sediment production mechanisms in the various basins and no doubt to sediment load measurement errors. Perhaps just as important may be the assumption inherent in the plot that 100% of the drainage basin is contributing sediment to the point where the measurement is taken. This aspect of sediment contributing area has been examined by Campbell (1978) for the lower Red Deer River basin in Alberta. While it is well recognized that the badlands area, between Drumheller and Bindloss gauging sites on the Red Deer River, contributes a

significant amount of sediment to the river, (in the order of 1 Mt/a according to Hydrocon (1987)), the actual sediment-producing area is only in the order of 800 km², which results in a "true" sediment yield of 1250 t/km².

3.4.3 Alberta Projects

The sediment yield data for Alberta presented in Figure 3.4.1 is based on a varied scope of engineering investigations and represents a wide range of basin characteristics:

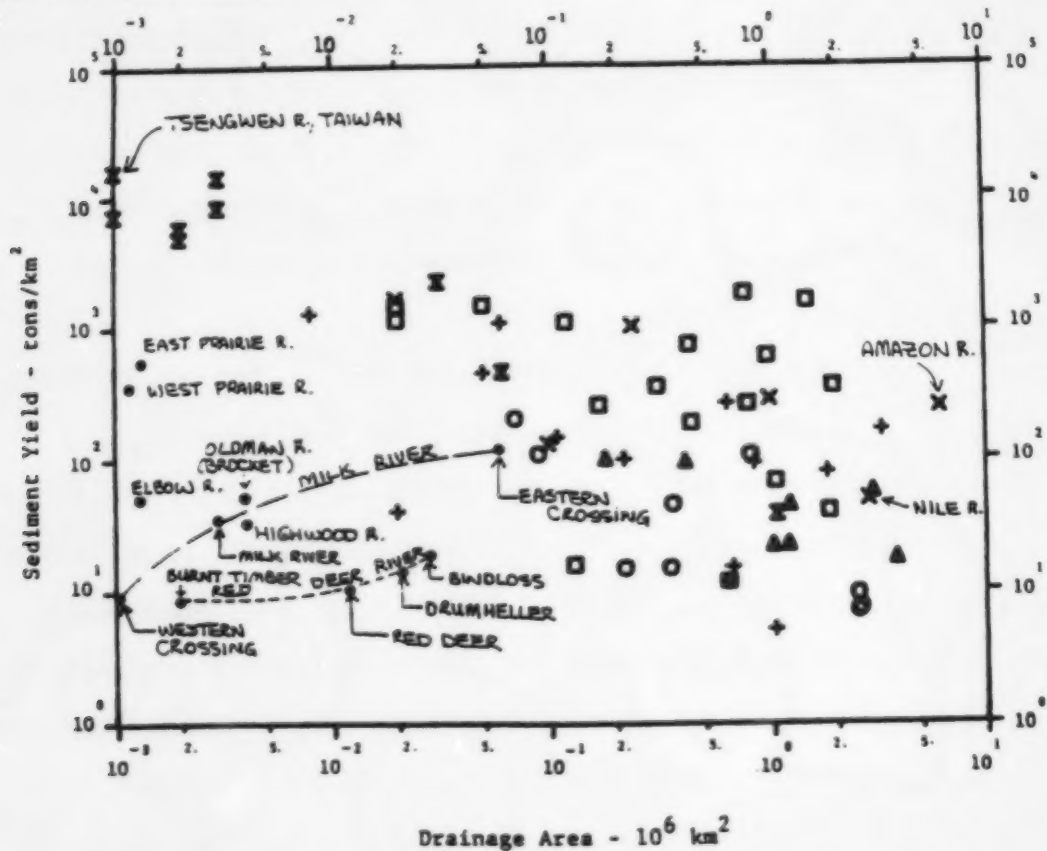


Figure 3.4.1 Sediment Yield Versus Drainage Area of World Rivers
(Measured Suspended Loads)

- East Prairie and West Prairie Rivers: Studies by Outhet (1977) and Northwest Hydraulics Consultant Ltd. (1984) have quantified the amount of sediment emanating from channel degradation caused by over-steepening of channel gradients for flood control. Other naturally-occurring sediment sources in the basins also have been quantified, as a part of investigations for water management projects in the lower portion of the catchments (Hydrocon, 1984).

- Elbow River: Investigations by Hudson (1983a) have indicated that sediment and water production in the Elbow River basin upstream of Calgary is highest in the downstream plains and foothills areas, respectively. Thus, a dam proposed for the upstream portion of the watershed (to provide flood control for Calgary and trap sediment so as to increase the life expectancy of Glenmore Reservoir), would not have been effectual.

- Oldman River: The Brocket site (Day and Sptizer, 1985b) has been an important site for sediment data used in reservoir sedimentation studies for the Oldman River Dam (NHCL, 1978). A recent investigation by Hudson and Askin (1987) has indicated that a significant portion of the sediment load passing by Brocket originates from several diffuse upland sources (gullies) in the Cardston Plain as well as from isolated eroding cliffs alongside the river channel.

- Milk River: Sediment data for the Milk River (Spitzer, 1987), have been useful in examining sediment loads along the channel, and the effects of an interbasin diversion (McLean and Beckstead, 1981, 1987).
- Highwood River: Sediment data for the Highwood River have been gathered at a gauging station near the mouth to determine the sediment characteristics of the basin (Day and Spitzer, 1985a).
- Red Deer River: Sediment data for the Red Deer River (Hydrocon, 1987), indicates that Dickson Dam will have little impact on the downstream sediment regime (NHCL, 1979). The data are also thought to be useful for scheduling water withdrawal at major pumping installations, and in assessing the role of the Red Deer River in contributing sediment to Lake Diefenbaker in Saskatchewan.

3.5 Importance of Sediment in Water Quality Assessments (L.R. Linton)

The concentration of suspended solids in the water column is itself considered to be a water quality variable since the presence of such solids can influence the utility of the water for human use, and can impact the aquatic biota. However, suspended solids can also have a very strong influence upon the fates and biological effects of nutrients and toxicants. The effects of suspended sediments on toxicants is discussed in section 3.5.1 while that on the biota is addressed in section 3.5.2.

3.5.1 Suspended Solids, Nutrients and Toxicants

Suspended solids play a critical role in the physical movement, chemical speciation and biological fate of toxic metals and organics, and is often considered to be their major transport medium. However, the chemical and physical mechanisms which influence these processes differ for metals and organics.

3.5.1.1 Adsorption

Iron and manganese hydroxides are often natural components of mineral-based suspended sediments, such as those obtained from the bedrock. These hydroxides have strong affinities for many toxic metals such as: copper, cobalt, nickel, arsenic and zinc, and can remove them from solution by adsorption. Organic matter which leaches from living or dead material can coat the surface of inorganic suspended sediment particles. Since many organic toxicants (e.g. PCB, insecticides) have very low solubility in water but high solubility in organic material, they tend to be bound to this organic component of suspended solids particles. For both metals and toxic organics the proportion that is bound to sediment versus remaining in solution particles depends upon a variety of physical and chemical properties of the toxicant (e.g. solubility), the suspended sediment (e.g. composition) and the environment (e.g. temperature and pH).

3.5.1.2 Toxicity

Toxic pollutants must be in solution in order to exert their toxic effects so their toxicity is reduced in proportion to the amount bound to suspended solids.

3.5.1.3 Transport and Deposition

In the bound state, the transport and deposition of toxics is the same as that for the particles to which they are attached, which depends upon a variety of factors such as the geologic history of the region, discharge regime, and type of material from which the particles are formed (Ongley and Blachford, 1982).

3.5.1.4 Fate

Once the suspended particles become sedimented a host of complex biogeochemical transformations can occur: 1) The simple case is that the sediments become buried by other sediments and the toxicant is removed from the biosphere. 2) Reactions can occur which liberate the toxic materials back into the water column, or transform them into more or less toxic substances. Release into the water column can occur due to factors such as changes in pH or oxygen concentrations, and organic toxicants can be released from the sediment particles to which they are bound when the organic portion of the particles is decomposed. Under reducing conditions metal compounds can be formed, which (as in the case of methyl mercury) are extremely toxic and highly soluble, so as to readily re-enter the water

column and biosphere. 3) The sediments can be consumed by benthic feeding organisms that concentrate the toxicants in their body, thereby introducing them into the food chain or killing the organism. 4) The sediment can, at some later date, become resuspended and transported to a ~~new~~ location. Infrequent high flow events will scour depositional areas extensively and therefore liberate large amounts of toxicants that have been accumulating for extensive periods of time. Toxicants which were originally in very low concentrations and deposited over long time periods may now occur in high concentrations. In this fashion sediments act as a time delay mechanism on the potential action of toxicants and can amplify their toxic effects.

3.5.2 Suspended Sediments and the Aquatic Biota

Despite being able to measure many water quality variables with great precision and accuracy, water quality per se cannot be measured. It must be defined from the perspective of some particular use. For the present purposes water quality will be viewed from the ecological perspective, so the effect of suspended solids upon the aquatic biota will be considered and the effects of suspended sediment on various trophic levels of the ecosystem will be discussed.

3.5.2.1 Primary Producers

The source of energy for all biological systems is photosynthesizing organisms. In aquatic systems plant productivity is regulated by factors such as light, nutrients, carbon dioxide, and herbivory, all of which are

potentially altered by suspended sediments. With respect to suspended solids reducing light and therefore limiting primary production, there is mixed evidence as to its effectiveness, with some studies showing a very strong inverse relationship between concentrations of suspended solids and primary production rate, while other studies show little effect (Brown, 1975). The lack of consistency among the studies is likely related to the species of plant being studied, their growth form (planktonic vs. benthic), and specific habitat characteristics.

Plant nutrients like toxicants, can be bound to the surface of suspended sediment particles and therefore are not available for uptake by the plants. The mechanism of this binding is partly related to dissolved oxygen concentrations (redox potential) and this regulates the proportion of the nutrient which is bound versus free. Redox induced shifts in the equilibrium between the adsorbed and dissolved phases can be in opposite directions for different nutrients. For instance, phosphates are more tightly bound under high oxygen concentrations, while nitrates more loosely bound. As oxygen concentrations drop the phosphates tend to go into solution, while nitrates become adsorbed. In this way plants can be locally limited by different nutrients, depending upon environmental conditions.

Suspended sediments can also be an important transport mechanism for plant nutrients. Adsorbed compounds and ions are transported through lotic environments to depositional areas where they become part of the sediments.

If the depositional area is a lake which undergoes thermal stratification, complex cycles of dissolution and precipitation of the nutrients can contribute significantly to the trophic status of the lake.

3.5.2.2 Macroinvertebrates

In lotic systems, benthic macroinvertebrates are often specialized to utilise specific microhabitats such as certain surfaces of stones (e.g. upstream or downstream), or the spaces between stones. Many of the species which inhabit upstream, upper, or downstream surfaces of stones are filter feeders which use nets spun from material similar to spider web. Suspended sediments can clog these nets resulting in starvation. Many of the planktonic invertebrates (e.g. *Daphnia*) are filter feeders whose filtration apparatus can also be clogged by suspended sediments.

The interstices between stones are important microhabitats for many benthic macroinvertebrates and these spaces can become filled with sediments, thus excluding the species from the habitat.

Macroinvertebrates utilise specific locations for deposition of eggs and incubation of young. For instance, snails lay eggs on the surfaces of plants or stones. If these surfaces are covered with sediment, egg laying may not be successful, or if these surfaces become covered after eggs have been deposited, then the eggs or juveniles may be smothered.

A large proportion of the macroinvertebrate community (benthic and planktonic) consists of herbivores. For these species, detrimental effects

of suspended sediments on the primary producers will be reflected as reduction of their food resource and consequently their population sizes. Of course, this effect will also be transmitted to higher trophic levels (other invertebrates and fish).

3.5.1.2 Fish

The effects of suspended sediment on fish will not be essentially different from those on invertebrates. Food supplies, habitat and breeding places can be adversely affected, with concomitant influences upon population dynamics. Due to the economic and recreational importance of fish, we tend to be concerned about the health of their populations. However, we should not place undue emphasis on fish studies when assessing the potential effects of suspended sediments on the ecosystem. Narrowing our perspective to fish only tends to obscure the fact that the vigour of these populations is related not only to the proximate effects of suspended sediments upon fish, but also the effect of suspended sediments upon the resources of the fish (plants and invertebrates). We would be wise to understand the aquatic system as a system, and not as a series of discrete, unconnected elements (one of which is fish populations) to be studied in isolation.

3.5.3 The Relationship Between NFR and SS

Water Resources Branch (WRB) initiated collection of suspended sediment (SS) data in 1961 to assess the quantity, sources, transport rates, and destinations of sediment. Since a major objective of the studies was to estimate the quantity of material being transported, sampling effort was

focused on periods of high discharge (spring runoff and major storms) when the vast majority of the annual sediment load is moved.

Water Quality Branch (WQB) undertook broad spectrum monitoring to assess water quality in terms of physical and chemical characteristics, including residue (NFR). Water Quality Branch samples more sites than WRB, and these are sampled at monthly intervals.

Water Quality Branch and Water Resources Branch are essentially trying to measure the same quantity, however they use different field and laboratory techniques. It has been found (Linton et al., 1988) that there is a bias between the WQB estimate of NFR and the WRB estimate of SS. In general, SS values tend to be higher than NFR estimates, but the amount of bias is site specific. At some sites there is little difference between estimates, while at others they can differ by more than 50%. This complication makes pooling of NFR and SS data of questionable value until site specific conversion functions are available.

3.5.4 Issues

Estimates of transboundary loads of toxicants associated with sediments are of interest for transboundary issues or deposition in receiving lakes or reservoirs. WQB appears to be under-estimating suspended solids concentrations, so NFR is of limited value for these calculations. Since WRB has good estimates of SS it might appear that the contaminants-concentration data of WQB could be combined with the WRB SS data to obtain estimates of loads associated with suspended solids.

However, WQB analytic techniques do not differentiate between the dissolved and bound fractions of toxicants, so these calculations are not possible. Coordination of the objectives and data gathering efforts of the two branches is required and should be river-basin specific.

Since the fate and effects of dissolved toxicants, and toxicants associated with sediments are quite different, it is important that sampling and analytical techniques address both. However, suspended sediment concentrations are frequently too low for sufficient samples to be obtained from the 4-5 litre grab samples usually taken. Ongley and Blachford (1982) have addressed this problem in their work on the Bow, Oldman and North Saskatchewan rivers by using a continuous centrifuge at the sampling site to extract solids from large volumes of water. This is a large improvement in technique.

As discussed earlier, the fates (deposition, resuspension, chemical speciation) of bound toxicants are influenced by the basin's hydrologic regime. It is therefore desirable to co-ordinate the water quality sampling regime with river flows as was done by Ongley and Blachford (1982). Allan (1986) points out that the proportion of toxicant associated with particulate matter varies with the concentration of particulate matter (which in turn varies with flow), so the sampling regime must be co-ordinated with "suspended sediment events" as well as flow events.

3.6 Sediment Impacts on Fisheries (B.F. Bietz)

While in theory suspended solids are all non-dissolved materials in a water sample, in practice the cut-off between dissolved and suspended materials

is based on the ability of the materials to pass through a 0.4 micron filter. Total suspended solids can be further subdivided into settleable and non-settleable solids, with settleable solids defined as a volume of particles that will settle within an arbitrary time period. The settleable/non-settleable distinction is significant as the two fractions have different impacts on aquatic ecosystems.

The general impacts of sediments on fisheries have been well established. At sufficiently high concentrations within the water column, suspended solids can be directly lethal to fish, the mechanism being gill damage and eventual suffocation or increased susceptibility to other diseases. Lethal concentrations vary markedly between species of fish and due to physical differences in suspended materials (e.g. abrasiveness). At lower concentrations, growth and survival may be affected due to behavioural changes, primarily reduced feeding ability.

The more significant sediment impacts on fisheries likely result from settled sediments. Fish eggs and newly hatched embryos may be killed when fine sediments clog the interstitial spaces they occupy between the river gravels, cutting off water and oxygen flow. Similar mortality of dislocation of benthic invertebrates from sediment deposition may also occur, significantly reducing available food supplies.

Many fish communities naturally experience short-term periods of high suspended solids loadings in the water column and could be considered to be at least partially pre-adapted to such events. However, these

concentrations tend to occur during high flow periods, so the majority of the sediment load will remain in suspension and the events are of relatively short duration. It would appear likely that the greatest risk of sediment-related impacts in Alberta will occur in stream systems where sediment loadings occur during low flow periods (allowing sediment deposition) or when suspended sediment discharges are large and persistent. The Athabasca River system may be particularly vulnerable to future sediment impacts from surface mining and from pulp and paper development. Surface mining for coal occurs in many of the smaller Athabasca River watersheds, and the effectiveness of their treatment systems is variable. Two pulp mills are now in operation, a third is under construction and two more are planned. Finally, mine water from one large oil sands surface mine is currently being discharged into the lower river reaches and a second oil sands surface mine is likely to be developed.

No Alberta water quality guidelines currently distinguish between settleable and non-settleable solids. For example, current standards for Alberta East Slopes coal mines are the larger of either 50 mg/L, or 10 mg/L above backgrounds concentration, of total suspended solids. No research has been conducted in Alberta to provide a biological rationale for the above standards or to distinguish between total and settleable solids effects. Furthermore, operating experience indicates that no practical technology exists to allow East Slopes surface mines to consistently meet these guidelines. No consistent guidelines exist for Alberta pulpmill solids loadings and an ad hoc approach is being used to set their effluent

limits, with no obvious environmental rationale. In light of the recent movement by Alberta Environment to set environmentally meaningful water criteria and to significantly increase enforcement of those criteria, a concerted effort will be required to develop new guidelines.

4. PANEL DISCUSSION

4.1 Sediment Survey Section (T.J. Day)

MANDATE

The sediment monitoring activities of Water Survey of Canada Division are mandated through legislation including the Boundary Waters Treaty Act, the International River Improvements Act, the Canada Water Act, the Northern Inland Waters Act, the Fisheries Act and the recent Canadian Environmental Protection Act. There is also a general federal mandate for conducting research, collecting data and maintaining inventories relating to surface and subsurface waters, pollutants and contaminants, fisheries and aquatic ecosystem, etc. Furthermore, there is a general responsibility for planning and managing water resources where there is a significant national interest.

Within this mandate the Sediment Survey Section operates under the functional management policy of the Inland Waters Directorate. The Section is responsible for providing technical advice to the regional offices of the Water Resources Branch.

ISSUES

The sediment-related issues being addressed by these activities include:

* Water Resources Engineering Issues

- ° There is a wide range of sediment concerns relating to 'traditional' water resources problems in Canada. These include reservoir sedimentation concerns in the Prairies and navigation channel dredging in the Fraser River. These concerns continue to exist, and as human use of waterways increase, will become more prevalent.

* Environmental Quality Issues

- ° Over the past few years our group has made overtures to agencies and individuals in agriculture, fisheries, and water quality in order to determine their need for sediment data and information, and to assess how our monitoring and study activities can assist them.
- ° Our major focus has been our sister Water Quality Branch (Inland Waters Directorate). Efforts include intercomparison of samplers and laboratory procedures, joint usage of sediment data bases, and formulation of sediment quality guidelines.

CURRENT INITIATIVES AND STUDIES

Some typical initiatives are categorized below:

* Network Planning

- ° A major effort to implement a process for regularly reviewing and interpreting data programs is now underway.
- ° Current network plans are being formulated following a national Water Resources Branch agreement.

* Inter-program Activities

- ° A Task Force is now evaluating the needs and opportunities for integrating water quality and sediment monitoring activities within the Inland Waters Directorate.

* Data Analysis and Information

- ° Extracting the information content of the existing sediment data base remains a key focus.
- ° The systematic evaluation of station data continues and new interpretations are continually being sought to make these data applicable to a broader range of users.

* Methods and Equipment

- ° A systematic evaluation of the field performance of samplers and procedures is in progress. It is vital to be able to document the variability in our data. The effect of laboratory procedures is also being considered.

FUTURE DIRECTION

Over the next few years, the Section shall continue to encourage the regional Water Resources Branch offices to follow the national strategy developed for sediment monitoring activities. The emphasis will be diversity - ranging from improving management and communications, continuing data analysis efforts, etc. The greatest challenge is in evaluating opportunities and needs in environmental applications and developing a viable response.

ORGANIZATION

The Section is part of the Water Survey of Canada Division, Water Resources Branch in Hull, P.Q. The organization of the Section is attached:

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- Sediment Computations Officer
 - data computation
 - laboratories
 - publications

4.2 Water Resources Branch (M.O. Spitzer)

MANDATE

In the Western and Northern Region (WNR) the Water Resources Branch (WRB) became involved in the collection of sediment data in the early 1960's. The actual sediment program was started by the PFRA in the fifties primarily to assess "reservoir life". The take-over by the WRB made sense in that the transport of sediment is inextricably linked to the stream discharge. The emphasis of the WRB program was on the detailed collection of suspended sediment data at a few sites on a long-term basis for engineering applications.

Canada's involvement in the collection of sediment data was formalized with the signing of the Cost-Sharing Agreement for water quantity surveys with the individual provinces in 1975. In this agreement water quantity stations are defined as "any location where surveys are undertaken to collect streamflow, or water level, or suspended sediment, or bed material, or bed load data singly or in combination".

A review of the Federal involvement in sediment data collection was conducted by a task force in 1979. This task force determined that even though sediments were not specifically mentioned per se in the legislation or major policy documents, nonetheless they found that there were many problems impacting on federal responsibility which required sediment information. They determined that in the interests of efficiency and cost-effectiveness it made sense to locate the federal Government's

expertise in an agency which also has responsibility for water quantity matters.

ISSUES

The traditional approach of comprehensive data collection (full program stations) has been modified somewhat in that fewer full program stations are being operated, but significantly more miscellaneous programs (suspended sediment sample collected in each visit by the field technician to the site) stations are being operated, thus providing at least some information at many more sites throughout Alberta.

The Calgary District continues to collect sediment data primarily for traditional engineering applications. At the same time, however, it has been recognized that sediments play an important role in environmental problems and as a result WRB has been looking at its collection program from the aspect of applicability to this role.

CURRENT INITIATIVES/STUDIES

During the last several years the emphasis of the Calgary District has been to evaluate the sediment data collected at the long-term, full program stations, and modifying the programs at these sites based on the findings of the evaluations. The evaluation of five full program stations has been completed, and data compilations for these sites are contained in the following reports:

Sediment Station Analyses: Highwood River Near the Mouth
(Day and Spitzer, 1985a)

Sediment Station Analyses: Oldman River Near Brocket
(Day and Spitzer, 1985b)

Sediment Station Analyses: Red Deer River (at Red Deer, at Drumheller,
near Bindloss) (Hydrocon, 1987)

Similarly, a report "Sediment Data Milk River Basin" was prepared detailing
all the available sediment data collected at a number of sites along the
Milk River (Spitzer, 1987).

The analyses of long-term, full program stations continues with work in
progress on: Sediment Station Analyses: South Saskatchewan River at
Highway 41 and requests for proposals issued for sediment station analyses
for the "lower Athabasca River system" and for the "Lesser Slave Lake
basin".

In addition, several specialized studies were or are being conducted
including:

- "An Interpretative Study of the Upper Oldman River Sediment
Regime" (Hudson and Askin, 1987)
- "K-Factor Analysis Red Deer River at Drumheller":
(Hydrocon, 1987)
- "Sediment Characteristics in Alberta":
(Hudson, in progress)

In the forth-coming year (1989/90) it is expected that the series of sediment station analyses reports will be completed with two additional reports:

Sediment Station Analyses: Peace River Basin

Sediment Station Analyses: Oldman River Basin.

Sediment station management plans have been initiated for some 156 active and discontinued sediment stations. These management plans will be completed in 1989/90 and will be updated annually. The program at each active site will be conducted according to these plans.

FUTURE DIRECTION

Of course, much of the future direction of the Calgary District sediment program will be tailored by the results of this workshop and by the outcome of the National Sediment Meeting, which is being conducted immediately following this workshop.

ORGANIZATION

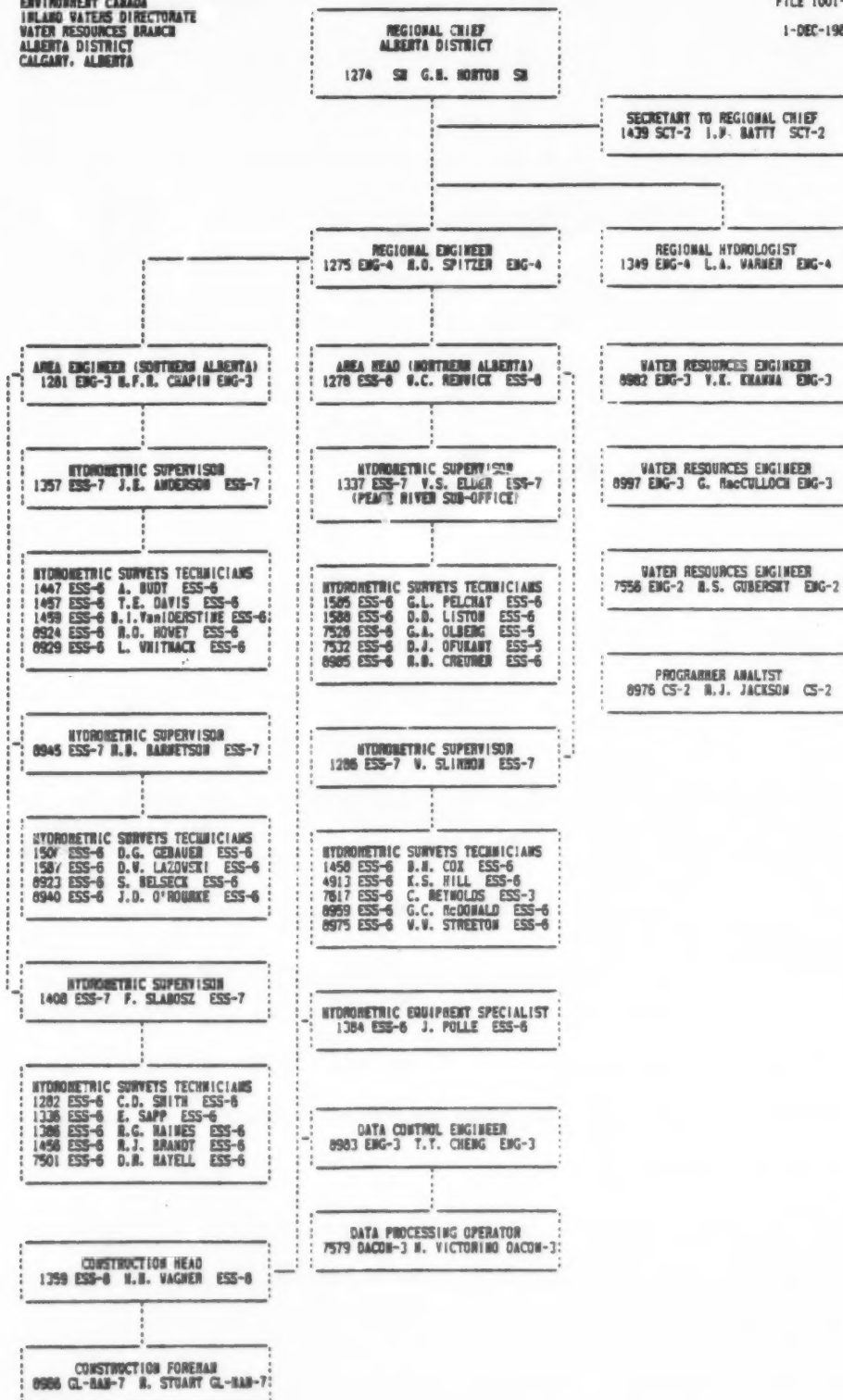
All the hydrometric field staff of the Alberta District are involved in the sediment program to some degree. Should information be required about the program, contact:

N. (Nick) Chapin: 292-5313, Area Engineer, Alberta Sediment Program,
or alternately,

M. (Milt) Spitzer: 292-5317, Regional Engineer, WSC, Calgary.

ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE
WATER RESOURCES BRANCH
ALBERTA DISTRICT
CALGARY, ALBERTA

FILE 1001-4
1-DEC-1988



4.3 Alberta River Engineering Branch (R. Quazi)

MANDATE

The River Engineering Branch in Alberta Environment has the mandate to provide technical expertise in all areas related to stability of bed and banks of water bodies. This mandate includes all aspects of generation, movement and deposition of waterborne sediments in Alberta.

ISSUES

The sediment-related issues in our program have to do with:

- a) Design of water management structures; and
- b) Evaluation and review for licensing and permits, development proposals and their sediment impacts.

For the design of water management structures (i.e., dams, canals, weirs, intakes and outfalls) sediment is considered as an important element for sizing and operation of the structure. Also impacts of sediment retention such as in dams are evaluated as well as impacts on the downstream channel. Licences and permits for activities such as:

- river crossing
- water intakes
- gravel removal
- river training
- bank protection

Short-term changes in sediment quantity and distribution are analyzed to determine impacts on fishery resources and other downstream developments in the zone of development.

Often, concerns regarding changes in land use and its impact on sediment production are handled for proposed land clearing and drainage schemes.

CURRENT INITIATIVES

Some of the current studies underway are:

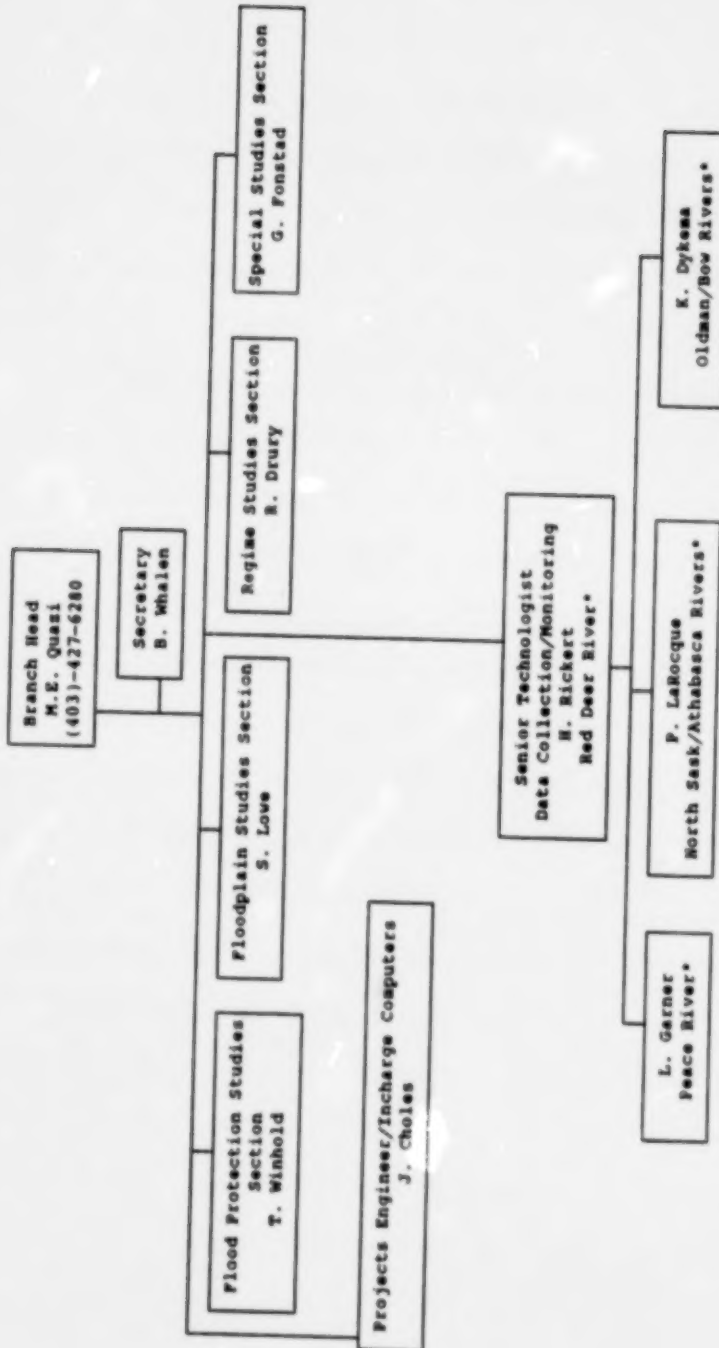
- a) Milk River storage proposal;
- b) Pembina River flood control;
- c) Savridge Creek debris control alternatives;
- d) East/West Prairie delta flood management; and
- e) McLeod River basin sediment balance.

FUTURE DIRECTION

Environmental water quality is becoming more prominent in our department. Issues related to the role of sediment in the transport of pollutants are becoming more pronounced. Future planning for data collection has to address these new needs. With major rehabilitation works on the southern Alberta canals nearing completion, data on sediment movement in irrigation canals has to be initiated. Sediment movement versus fisheries management has to be studied in more detail, as fishery concerns are becoming more pronounced.

ORGANIZATION

RIVER ENGINEERING BRANCH
ORGANIZATION CHART



*Basin Responsibility for Assessments

4.4 Alberta Research Council (D.D. Andres)

MANDATE

Sediment-related activities at the Alberta Research Council are being addressed primarily under the auspices of the Alberta Cooperative Research Program in Surface Water Engineering. The active members of the program are the Alberta Research Council, Alberta Transportation and Utilities, and Alberta Environment. The Department of Civil Engineering of the University of Alberta plays somewhat of an advisory role. Initially, objectives of the sediment research were defined to address the impact sediment transport has on river processes and ultimately on the management and development of rivers. This led to the very early work directed towards field measurements of bed material transport, bank erosion, and bed scour. Since that initial effort in the late 1960's and early 1970's, work has expanded into areas of sediment yield, from both regional and smaller scale "plot" perspectives.

ISSUES

One of the major difficulties in characterizing bed and bank scour in some of our more contemporary investigations is the role played by bed material load. Recognizing that scour cannot be completely quantified without knowing the sediment and sediment load characteristics resulted in interest in quantifying bed load in the early 1980's and a project was designed to carry out bed load measurements in gravel-bed streams. Unfortunately,

funding for this work has not been forthcoming due to the unfavourable economic conditions coupled with tremendous effort required to fully understand the transport problems and to be able to confidently transpose the knowledge to a specific problem or condition.

Instead, we have been addressing issues related to the source, fate, and impact of sediment. Most of the work has been directed towards a regional evaluation of sediment yield. An important facet of this work has been to define sediment sources, the characteristics of those sources, and the way the sediment is distributed in the river systems during transport.

FUTURE DIRECTION

Future work and/or directions in sediment at Alberta Research Council is related to four main points. In traditional areas of river engineering, such as drainage channel design, local scour assessment, pipeline/bridge crossing design, erosion protection, and water intake design, the quantity and characteristics of sediment does not seem to be of major concern. Many of the design techniques do not include sediment considerations other than in somewhat of a subjective sense. As a result, much of the available sediment data are hardly ever used. The exception seems to be in the design of on-stream reservoirs. Here sediment data are most always utilized, but the sediment problem almost never becomes a serious concern. The volume of many of the reservoirs is so large, compared to the annual sediment inflow, the concern need be cursory, at most.

Smaller on-stream reservoirs, whose numbers seem to be increasing due to reactions to the perceived impending drought, are the exceptions and their design need careful scrutiny from a sediment point of view. Many of these developments are on smaller streams where there is no sediment information nor is there time and money for site specific measurements. This underlines the importance of defining regional sediment yields, even in a very broad manner. Hence our current efforts.

The transport of pollutants attached to sediment particles may become an important issue in Alberta. At this time the severity of the problem is not known. However, given the industrialization of the province and the trends toward greater reliance on agricultural chemicals, some work is needed on developing field techniques and evaluating base line conditions in priority locations. I see this as being an area where Alberta Research Council can play a significant role.

Finally, I would like to address the biological impacts of short-term, high intensity sediment inputs. This is not a new issue, yet no resolution has been achieved over the last fifteen years. The biologists, on one hand, demand "zero tolerance" because they cannot define critical conditions. The water resource managers/developers, on the other hand, must proceed with development. This leaves the regulators and licensers to determine some middle ground, often without adequate information. I believe there is considerable room here for research and see this issue as one where significant headway can be made provided appropriate research plans are developed and implemented.

ORGANIZATION

AGENCY: Alberta Research Council
DIVISION: Natural Resources
DEPARTMENT: Resources Technologies
RESEARCH GROUP: Surface Water Engineering
PROFESSIONAL STAFF:

D.D. Andres, M.Sc., P.Eng. (450-5279)
Group Manager, Surface Water Engineering
- river mechanics
- ice hydraulics
- dispersion

H.R. Hudson, Ph.D. (450-5275)
Research Officer
- hydrology
- sediment transport
- geomorphology

G. Van der Vinne, M.Sc., P.Eng. (450-5276)
Research Officer
- dispersion
- fluid mechanics
- ice mechanics
- hydraulics
- fishways

C. Malcovish, M.Sc., P.Eng. (450-5247)
Contract Researcher
- river engineering
- hydrology
- sediment transport
- hydraulic structures

V.K. Arora, M.Sc. (450-5267)
Research Officer
- computer programming
- systems analysis and software design
- data base management

TECHNICAL STAFF:

J. Thompson
T. Ridgway
B. Trevor
P. Mostert

4.5 Water Quality Branch (T. Dafoe)

PROGRAM

The Water Quality Branch is composed of three separate divisions each of which is involved in sediments to one degree or other. I will begin by briefly describing the organizational structure of the branch before outlining the activities of these divisions as they relate to this topic.

The Water Quality Branch has regional offices in Moncton, Longueuil, Burlington, Regina and Vancouver. It also has sub-offices in Winnipeg, Calgary and Yellowknife. The headquarters office is in Hull with the National Water Quality Laboratory, which is considered as part of headquarters operations, is located at the CCIW in Burlington. In most regions and at headquarters the Branch is divided into three divisions. These are the Monitoring and Surveys Division, the Objectives Division, and Laboratory Operations Division. A new division, Water Quality Assessments Division has just recently been formed at headquarters to address State of the Environment Reporting.

I will now briefly describe the activities of each of the divisions as they relate to sediments:

Objectives Division -- With the successful development of the Canadian Water Quality Guidelines under the auspices of the Canadian Council of Resource and Environment Ministers (CCREM), this group has been asked to develop guidelines for PCBs in sediments and is studying the use and

development of sediment quality guidelines for Canada. The purpose of having guidelines for various contaminants in sediments becomes particularly important when the sediments are proposed to be disturbed, by dredging for instance. This type of activity can reintroduce into the water column a variety of contaminants such as toxic organic chemicals and metals associated with the sediments.

National Water Quality Laboratory (NWQL)-- The laboratory, located at the CCIW in Burlington, is the centre where the more complex analyses associated with water quality are carried out. Amongst these are the analyses of sediments for metals and organic constituents. In addition, in cooperation with NWRI, new methods and Standard Reference Materials are developed for the analysis of sediments.

Monitoring and Surveys Division -- This division is generally responsible for all the design and sampling related to the sediment work in the Branch. Projects for the sampling of bottom and suspended sediments are designed and implemented. This group has also developed innovative ways to sample for suspended sediments in association with the research community at NWRI. Although sediment sampling and analysis is not a large portion of the program it is a very important one and is gaining in importance. As the role of sediments as a major pathway in the transport of a variety of pollutants has become better defined, there has been more focus on the nature and loads associated with these.

The Water Quality Branch as with the rest of IWD is a regionalized operation. There are five regional offices, one is in Regina and the

centre for activities in the Prairie Provinces and the Northwest Territories. The region is divided into sub-regions with the Alberta office in Calgary. The Alberta sediment activities in water quality are the responsibility of Howard Block. Howard will be able to help those interested to obtain information and data on sediments to date.

CURRENT INITIATIVES

I alluded earlier to some of the more innovative activities of the Branch aimed at a better understanding of the concentrations of contaminants associated with suspended sediments in particular. These I will now describe in more detail.

Goulden Liquid-Liquid Extractor -- This device developed at NWRI allows us to extract relatively large (20 litres) volumes of water in the field with an organic solvent (methylene chloride). The solvent is then bottled and shipped to the laboratory for analysis. The water is extracted counter currently with the solvent and small amounts of solvent added to balance losses due to solution of the solvent in water. The additional solvent is added such that there are no dissolved contaminants lost. This apparatus provides a total concentration of contaminants in both the water and suspended sediments. Field trials with this device have been very satisfactory.

Seastar Resin Extractor -- This sampler developed and manufactured by Seastar Instruments Ltd. of Sydney B.C. samples in-situ. The instrument was developed initially for oceanographic work and operates effectively in

freshwater environments where sediments are in lower concentrations. The instrument contains a pump, flow meter and battery pack and a resin column is fixed to the outside of the casing. The instrument is lowered to the desired location to be sampled. Sediments are collected on a filter that precedes the resin column. The resin column when suitably packaged can be mailed to the laboratory for analysis while the collected sediment is handled separately and shipped to the laboratory for analysis. This gives concentrations in both the water and sediment fractions separately. Field trials for this device have provided data comparable with other methods.

Westphalia Centrifuge -- This device can be set up to operate at pre-set times or operated continuously as required. The high speed centrifuge effectively separates very light weight materials that are of particular interest in the transport of organic contaminants. The device requires an external power supply, is relatively heavy and as a result is not easily manoeuvred in the field. The efficiency of sediment removal make it a useful tool to quantify the concentration of contaminants in the suspended sediments.

Westphalia Centrifuge/Seastar Sampler -- This hybrid sampler allows the use of the best features of two technologies and was developed and first used in the Quebec region. The centrifuge and resin sampler are operated in series.

Suspended sediments are removed by the centrifuge while the "clarified" water is passed through the resin column. This provides good control of the amounts of water passed through the respective instruments and

relatively easy calculation of the concentrations of contaminants in each of the media. Field results are very good while the logistical problems tend to be greater due to the weight and size of the centrifuge and ancillary equipment.

FUTURE DIRECTION

The Water Quality Branch will be focusing its efforts in the near term on perfecting the techniques to obtain good data on sediment contamination. Longer term goals include the development of protocols and design tools to better select where and when to sample for contaminants in the environment. There is no doubt in my mind that to do a better job we need to marry the expertise of the Sediment Survey and the Water Quality Branch together with a dose of solid scientific expertise from the research communities to enable us to be successful.

ORGANIZATION

Address:

Water Quality Branch
854-200-4th Avenue S.E.
Calgary, Alberta
T2P 2M7

Key contacts:

Howard Block - District Resource officer - 292-5320

Larry Mottle - Water Resources Technologist - 292-5355

4.6 Prairie Farm Rehabilitation Administration (A.J. Cullen)

MANDATE

The PFRA was established in 1935 to undertake and promote methods of farm practice and water development which would minimize drought problems on the Prairies. To fulfil its mandate, PFRA has relied on a series of land utilization and water development programs.

ISSUES

Historically, PFRA's major requirement for sediment data has been to estimate the useful life of large onstream surface storage reservoirs. By virtue of their geometry, reservoirs are effective sediment traps. Recently, PFRA relied extensively on Water Survey of Canada (WSC) data and reports to calculate the useful life of the proposed Milk River Forks Reservoir (Kerber, 1975). The WSC data reveals that on an average year the total sediment of the Milk River at the proposed reservoir site is about 100 dam³ and thus the calculated useful reservoir life should exceed 200 years.

At present, PFRA has no organized program to collect sediment data. In a number of individual projects involving river intakes, sediment transport, shoreline erosion and sedimentation must be taken into consideration for the design. Historic survey data and aerial photos are the primary sources of data used to estimate future erosion and sedimentation processes.

The upstream slopes of earth dams are subject to erosion. PFRA has had a series of investigations and publications on the subject (Peters and Towle, 1979), but at present there are no organized studies.

FUTURE DIRECTION

Future PFRA sediment investigations are expected to be project specific to predict reservoir or pump intake shoreline erosion, or to calculate reservoir sedimentation.

ORGANIZATION

PFRA - AGRICULTURE CANADA
Alberta Regional Division

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Calgary, Alberta
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Ph. 403/292-5638

Actual Address:

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Facsimile 292-5659

Manager:

Andrew J. Cullen 292-5641

Secretary:

M. Pringle 292-5638

Administration:

C. Baker (Acting) 292-5639

Special Projects Engineer:

K. Davies 292-5723

Planning Engineer:

W. Nemanishen 292-5640

Operations Engineer

W.M. Huddleston 292-5642

District Office:

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Lethbridge, Alberta
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Officer-in-Charge:

M. Husdal 327-4410

4.6 Alberta Forestry, Lands and Wildlife (A. Locke)

MANDATE

In the province of Alberta, fisheries and fisheries habitat management is the responsibility of the Fish and Wildlife Division. The legislation which allows the agency to manage the fisheries is the Fisheries Act (Canada). This act is federal legislation which is administered and enforced in the province by the Fish and Wildlife Division.

In the Fisheries Act there are two sections which deal specifically with sediment. The first, deals with the harmful disruption of fish habitat, and the second, the deposit of a deleterious substance. These are respectively, Section 31(1) and Section 33(2). Our agency considers anthropogenic sources of sediment as a deleterious substance. You might consider sediment as being a "natural pollutant", since there is always some background or natural level in most streams at some time of the year. As you know suspended sediment is most noticeable in rivers and streams in Alberta during the spring runoff.

ISSUES

Briefly, suspended and settled sediment affects all life stages of fish, the egg, fry, juvenile and adult, as well as plants, invertebrates, and in general, the fish habitat or physical stream components, such as riffles and pools. Fish are affected by suspended sediment in several ways.

First, the protective mucous covering the scales and eyes is removed, making the fish vulnerable to infection and disease. Suspended sediment irritates the gills, causing the fish to secrete mucous. Persistent high concentrations can cause excessive mucous secretions, resulting in the gills no longer being able to absorb oxygen and the fish dies of asphyxiation. Secondly, suspended sediment lowers the feeding efficiency of fish that feed by sight. Therefore, it is important that the water be clear and relatively free of suspended sediment.

Fish habitat is also affected by suspended sediment. Suspended sediment absorbs radiant energy which increases the stream temperature. This results in stress on cool and cold-water species which have an upper lethal limit for temperature. Suspended sediment is abrasive and acts much like sandpaper. It scours and dislodges plants and aquatic insects associated with the streambed. The habitat and food source is lost resulting in reduced fish production. The stream water must be clear enough to permit sunlight to reach the stream bottom and the algae community, where most of the primary production of a stream occurs. Elimination of such production will severely affect invertebrate production. This effect passes through the entire food chain resulting in smaller and fewer fish.

As water movement slows, the suspended sediment begins to settle out covering the substrate. The eggs and recently hatched young no longer receive oxygen by intragravular flow and die. The silt fills in the gravel beds making them unsuitable for future spawning sites. Successful incubation of the eggs is dependent on a constant supply of water flowing through the gravel where the eggs have been laid. Recently-hatched fish

(alevins) remain in the streambed until they absorb their yolk sacs. The flowing water supplies the eggs and alevins with dissolved oxygen and removes waste products such as carbon dioxide and ammonia.

Gravel substrate are also the habitat for aquatic invertebrates. They are the major food supply for many species of fish. When these areas for invertebrate production become covered with sediment, the habitat is lost and subsequently fish production is reduced.

Although some fish or life stages are more tolerant of sediment than others, there is no fish species in Alberta which can withstand extended periods, for example hours or days, of high turbidity from suspended sediment. The type of material held in suspension, its settleable nature, the timing and duration of its release, as well as the fish species involved, their life stage and the nature of their habitat will predicate tolerances and compromises. As stated previously, sediment is considered to be a natural pollutant.

Sediment is introduced to watercourses as a result of various activities. Most common in Alberta, are stream crossings associated with road and pipeline construction. Other activities include timber harvesting, road construction, and strip or open pit mining to mention a few. In general whenever vegetation is removed and soil is laid bare to the elements, wind and particularly rain, erosion will occur and the sediment concentrations in streams will increase beyond their natural occurring background levels.

There is a tremendous volume of material written about sediment and its impact to the aquatic environment. In 1965 the European Inland Fisheries Advisory Committee (EIFAC) summarized a great deal of this information and produced a summary of sediment concentrations versus the quality of the fisheries. The United States Environmental Protection Agency adapted the 1965 guideline in establishing maximum concentrations of suspended solids. Briefly, these guidelines suggest levels of less than 25 mg/L will have no harmful effects on the fisheries and offers a high level of protection. Between 25 and 80 mg/L there will be moderate protection with good or moderate fisheries. Eighty to 400 mg/L, poor fisheries are likely and there is a low level of protection. Concentrations of suspended solids above 400 mg/L will offer very low protection with very poor fisheries existing.

Recently in 1987, the Canadian Council of Resource and Environment Ministers (CCREM) adopted the British Columbia guideline put forth in 1985. This guideline suggests suspended solids should not exceed 10 mg/L when background suspended solids concentrations are equal to or less than 100 mg/L. Suspended solids should not exceed 10 per cent of background concentrations when background concentrations are greater than 100 mg/L. The CCREM guidelines are very similar to the Fish and Wildlife Division guidelines developed approximately ten years ago.

The mandate to protect and enhance the fisheries in the province lies with the Fish and Wildlife Division. There are two main program areas that deal with the issue of sedimentation, habitat protection and habitat development. First on the protection side, the Fish and Wildlife Division

has developed several guidelines which describe the best possible practices to minimize the amount of sediment released to the aquatic environment. These fisheries habitat protection guidelines include: geophysical operations, pipeline crossing, vehicular access across watercourses, extraction of sand and gravel, timber harvesting and gold extraction. Included in these guidelines are acceptable concentrations of suspended sediment at point of discharge. These acceptable levels are summarized in a table format and they are set on a sliding scale related to background levels of suspended sediment in the receiving watercourse.

Referral systems, and intra-and inter-departmental committees where projects are reviewed is a major program area of the Habitat Branch. Hundreds of referrals are processed each month where conditions for development, based on the protection guidelines, are placed on various provincial permits.

On the development side, the Buck for Wildlife Program is a major initiative of the Fish and Wildlife Division. For the past 15 years, this program has worked to create or improve habitat for fish and wildlife. One of the programs within the Buck for Wildlife Program is designed to reduce siltation caused by livestock grazing the banks of streams and rivers. Fences are erected and watering alternatives or stations are provided. With much of Alberta's riparian habitat located on private land, Buck for Wildlife is investigating the possibility of initiating a pilot program to encourage landowners to preserve riparian habitat on their property. Part of this program involves various incentive options, including financial incentives, which will be evaluated.

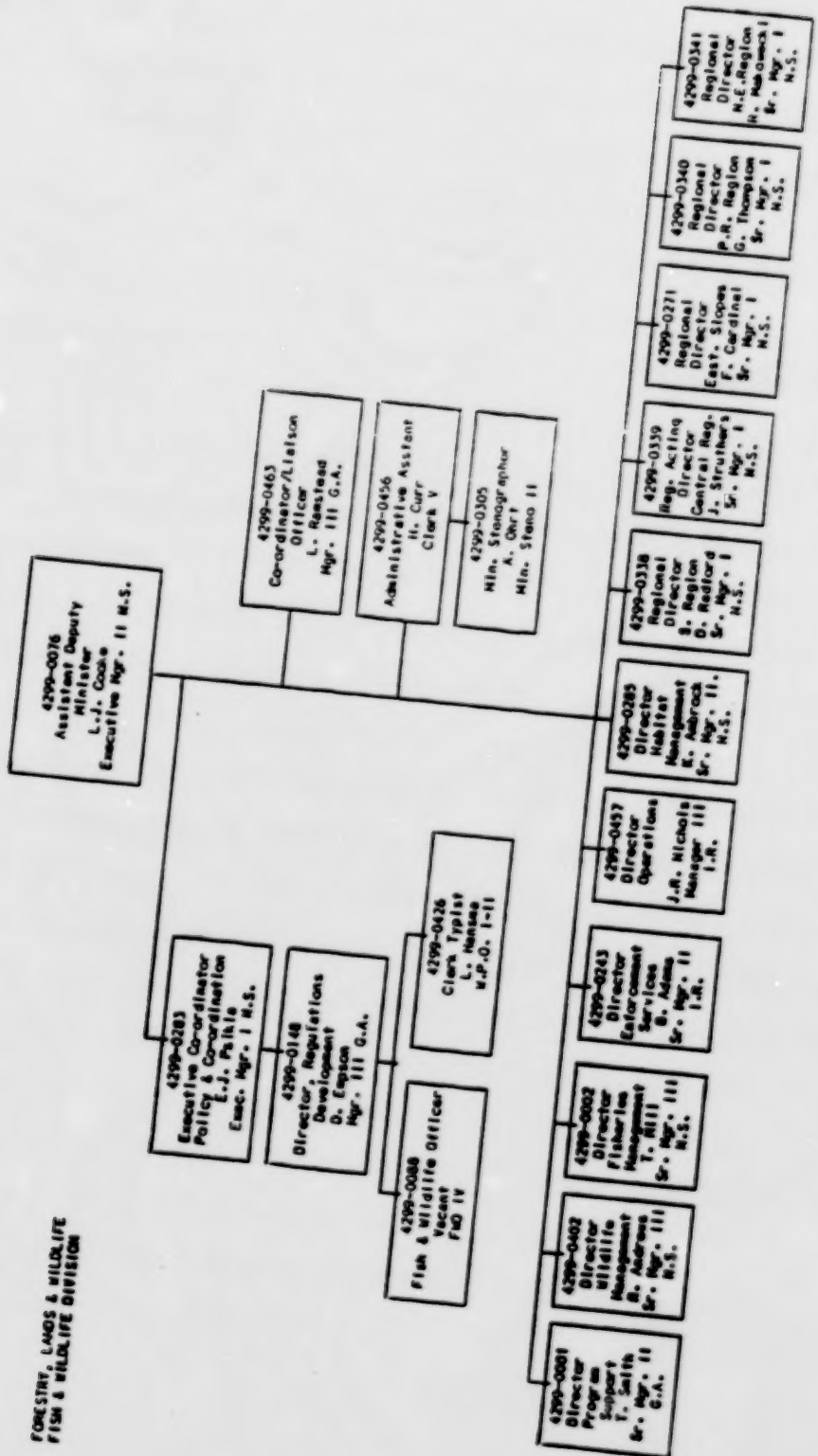
Another program area of the Fish and Wildlife Division related to sedimentation is enforcement. When all reasonable avenues of cooperation have been exhausted, in terms of setting and following conditions, the Fish and Wildlife Division has the legislated mandate to prosecute pursuant to Sections 31(1) and 33(2) of the Fisheries Act. Prosecution is the least desirable path for our agency to take. We prefer to cooperate with the proponent and reach an agreement before the project starts.

FUTURE DIRECTION

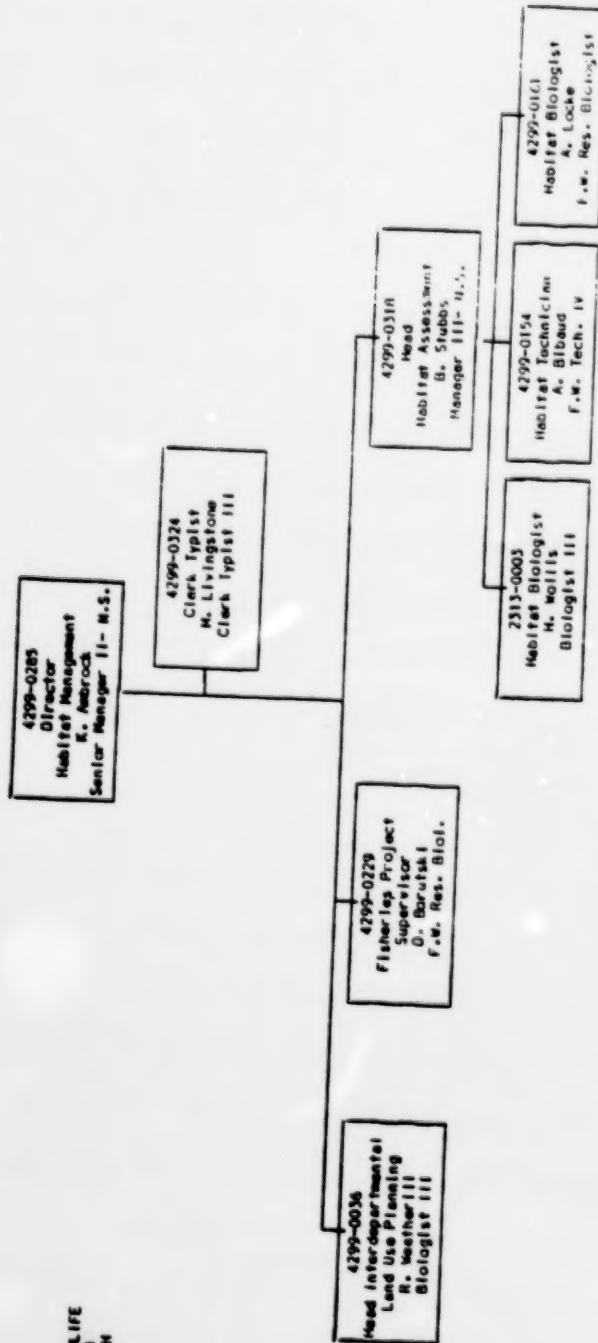
In summary, the written information on the impact of suspended and settled sediment on the aquatic environment is enormous and more than clearly implicates sediment both biologically as a "deleterious substance" and legally as defined in the Fisheries Act. Our role is not to carry out sediment-related research projects or programs, rather our efforts have focused on the development of a set of practical guidelines which, when followed by industry, will prevent the addition of sediment at a level that is known to be detrimental to fish and their habitats.

ORGANIZATION

FORESTRY, LANDS & WILDLIFE
FISH & WILDLIFE DIVISION



FORESTRY, LANDS AND WILDLIFE
FISH & WILDLIFE DIVISION
HABITAT MANAGEMENT BRANCH



5. Summary

The workshop demonstrated that there is considerable interest and work being done with streamborne sediments in Alberta. As the interest in sediment is diverse, it is apparent that a holistic approach to sediment problems is required to make proper interpretations and decisions.

Erosion from agricultural areas is a major concern, especially in those areas of the province where soil loss is severe. Considerable effort is being made to understand the processes and to evaluate agricultural practices which will reduce soil erosion. Even though there has been much research already done in this area, the linkage with what is eroding from the uplands to what is entering the river systems and its impacts on aquatic habitat is still not well defined. Recent studies in Alberta indicate that much of the sediment in the river systems is not being derived from upland (basin) sources.

Sediment loads which are derived from instream measurements are often converted to a yield (t/km) by dividing the load by the drainage area. This information, in turn, is used to evaluate the basin contribution for a variety of purposes. However, recent studies are showing that this approach provides very misleading information, which can have significant repercussions on, for example, design of instream structures. In fact, in most streams in Alberta only a small fraction of the basin area may be contributing most of the load. Therefore, an appreciation of sediment sources must become a critical component when determining sediment budgets.

Another concern with studying sediment transport in a river system relates to sediment sinks. In many cases the sinks are readily identifiable (e.g. lakes, reservoirs). However, due to regulation, many river reaches are aggrading which are not as apparent. Efforts to identify and quantify deposition in a river system will become increasingly important for properly analyzing the sediment regime.

An understanding of sediment processes and the concepts of "partial area" sediment contribution and aggrading reaches are important in the proper design of any instream projects. In Alberta sediment data are used extensively by engineers for design and conducting environmental assessments of such projects as: reservoirs, sedimentation ponds, channel diversions and pipeline crossings. The need for good reliable data will continue and become increasingly important for undertaking environmental assessments.

The detrimental impacts of sediment on the aquatic ecosystem has long been understood by biologists and taken into account in water quality assessments. However, the role and importance of sediment as a transport medium for various contaminants has just recently come to light. In future, water quality assessments will require specific information and a more thorough knowledge of sediment quality and sediment regimes of Alberta rivers to address growing environmental concerns.

To protect fisheries, Alberta has established guidelines for restricting the level of suspended sediment that can be discharged into a stream. Considerable concern has been raised as to whether the guidelines are

scientifically viable. It is suggested that more comprehensive (settleable and non-settleable) guidelines need to be developed that better reflect environmental rationale.

In terms of research, continued effort to link what is being eroded from the watershed to what is entering the river system will remain fundamentally important. Continued research in assessing the contribution of different sediment sources within a drainage basin is needed to help further support and apply the "partial area" concept. An appreciation of the amount of sediment being eroded from agricultural areas has added importance as it relates to an infusion of contaminants (e.g. fertilisers, pesticides). There is a need in Alberta to assess the role of sediment as a transport medium and to document contaminant levels associated with sediment, as limited information currently exists.

The sediment network appears to have reasonably covered the province in providing adequate base line information. There are however two regional areas where future work should be focused. The first is the irrigation/canal systems where currently data collection has been non-existent. Data could be used to address channel stability problems or to help assess sediment contributions from agricultural areas. The second area is the coal mining districts. Good sediment data can be used to help document environmental conditions or be used to make an assessment on mining operations (e.g. trapping efficiency of sedimentation ponds).

From a management perspective there are a number of initiatives that could be pursued which would help in delivering more effective programs. An

advisory group, comprising individuals from different backgrounds should be established to help provide a more diverse view on the use of sediment data for both engineering and environmental applications. Effort should also be made to establish a working group to help derive more scientifically viable sediment discharge guidelines. Finally, as sediment quality concerns increase there is a need to establish closer working relationships among agencies so as to provide the correct information to address these problems.

6. Recommendations

The workshop was successful in meeting its main objective of familiarizing and updating the water resources community in Alberta on the range of interests and activities relating to streamborne sediments. For the Water Resources Branch this workshop initiative has raised the profile of its sediment monitoring activities, as evidenced by thirty requests for sediment reports.

Recommendation: To continue the momentum generated by the workshop and to further focus interests, it is recommended that specific topic workshops (e.g. sediments in water quality assessments, off-farm sediment impacts) be organized in co-operation with the appropriate agencies and individuals.

As indicated by the discussions of the technical session, a multidisciplinary perspective is needed to address environmental concerns relating to streamborne sediments. Concurrently, there is a further need to develop a mechanism to assist agencies to focus on sediment problems. From the panel session it was obvious that like water, sediment is a factor common to any engineering and environmental water resources related activity. However, these needs are diverse and do not represent a major focus in most of the organizations.

Recommendation: The Water Resources Branch, in co-operation with the other agencies, consulting firms and academics identified through this workshop, establish a Technical Advisory Group with the responsibilities of providing advice on sediment problems, research and program needs. This Technical Advisory Group could also be used to guide the workshops recommended above.

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T0J 3H0

DAVID N. GRAVELAND 320-0411
3425-23RD AVENUE SOUTH
LETHBRIDGE, AB.
T1K 4K2

WILLIAM GUMMER (306) 780-5322
CHIEF, WATER QUALITY BRANCH
ENVIRONMENT CANADA
MOTHERWELL BUILDING
1901 VICTORIA AVENUE
REGINA, SK.
S4P 3R4

R. A. HALE (204) 949-7174
WATER RESOURCES BRANCH
ENVIRONMENT CANADA
521; 269 MAIN STREET
WINNIPEG, MB.
R3C 1B2

R. A. HALLIDAY (306) 780-5319
DIRECTOR
WESTERN & NORTHERN REGION
CONSERVATION & PROTECTION
ENVIRONMENT CANADA
INLAND WATERS DIRECTORATE
MOTHERWELL BUILDING
1901 VICTORIA AVENUE
REGINA, SK.
S4P 3R4

* HAROLD HAMILTON 247-6613
HYDROQUAL
380; 4500-16TH AVENUE N.W.
CALGARY, AB.
T3B 0M6

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

DAVID B. HANSON (406) 449-5263
CHIEF, INTERNATIONAL SECTION
U. S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
FEDERAL BUILDING, ROOM 428
301 SOUTH PARK AVENUE, DRAWER 10076
HELENA, MT. 59626
U.S.A.

* DAVID HARVEY (819) 953-1546
ENVIRONMENT CANADA
WATER RESOURCES BRANCH
HYDROLOGY DIVISION
OTTAWA, ON.
K1A 0H3

RICHARD (DICK) HAYWOOD 381-5338
ALBERTA AGRICULTURE
CONSERVATION & DEVELOPMENT BRANCH
AGRICULTURE CENTRE
JAIL ROAD
LETHBRIDGE, AB.
T1J 4C7

* LARRY HEINZE (306) 780-5347
WATER RESOURCES BRANCH
ENVIRONMENT CANADA
210; 1102-8TH AVENUE
REGINA, SK.
S4R 1C9

ALLAN HERBIG 223-2148
TABER IRRIGATION DISTRICT
P. O. BOX 129
TABER, AB.

* ROSS HERRINGTON (306) 780-5337
REGIONAL ENGINEER
WATER RESOURCES BRANCH
ENVIRONMENT CANADA
210; 1102-8TH AVENUE
REGINA, SK.
S4R 1C9

LEN HILLS 220-5841
DEPT. GEOLOGY & GEOPHYSICS
UNIVERSITY OF CALGARY
2500 UNIVERSITY DRIVE N.W.
CALGARY, AB.
T2N 1N4

MAILING LIST	TELEPHONE NUMBER
* ATTENDED SEMINAR	
UPALI HIPPOLA ALBERTA ENVIRONMENT DESIGN AND CONSTRUCTION DIVISION 8TH FLOOR, OXBRIDGE PLACE 9820-106 STREET EDMONTON, AB. T5K 2J6	427-6146
* DAVID HISLOP CH2M HILL 11TH FLOOR 815-8TH AVENUE S.W. CALGARY, AB. T2P 3P2	237-9300
JOHN HODGSON STANLEY ASSOCIATES ENGINEERING LTD. 10160-112TH STREET EDMONTON, AB. T5K 2L6	423-4777
* PERRY C. HOLINSHEAD HYDROMETRIC SERVICES LTD. 385 NORTHMOUNT DR. N.W. CALGARY, AB. T2K 3H4	289-6280
* ROBERT (BOB) HOWITT ALBERTA RESEARCH COUNCIL RESOURCE TECHNOLOGIES DEPT. BOX 8330, POSTAL STATION 'F' EDMONTON, AB. T6H 5X2	438-7514
* DR. HENRY R. HUDSON ALBERTA RESEARCH COUNCIL RESOURCE TECHNOLOGIES DEPT. BOX 8330, POSTAL STATION 'F' EDMONTON, AB. T6H 5X2	450-5275
G. A. (BILL) IRVINE REID CROWTHER & PARTNERS LTD. 7410 BLACKFOOT TRAIL S.E. CALGARY, AB. T2H 1M5	253-3301

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

* DOUG JAMIESON PRODUCTION ENGINEER WATER WORKS DIVISION CITY OF CALGARY P. O. BOX 2100, STATION "M" CALGARY, AB. T2P 2M5	268-2702
RODNEY JONES ALBERTA AGRICULTURE IRRIGATION BRANCH PROVINCIAL BUILDING P. O. BOX 778 BROOKS, AB. T0J 0J0	362-1212
RON JONES ENVIRONMENTAL CONTROL OFFICER P. O. BOX 100 FORDING COAL LTD. ELKFORD, BC. V0B 1H0	(604) 865-2271
L. J. KAMP WATER RESOURCES BRANCH ENVIRONMENT CANADA 75 FARQUHAR STREET GUELPH, ON. N1H 3N4	(519) 821-0110
J. BRYAN KEMPER PLANNING SERVICES BRANCH ALBERTA ENVIRONMENT 9TH FLOOR, OXBRIDGE PLACE 9820-106TH STREET EDMONTON, AB. T5K 2J6	
* ROBERT (ROB) KENT ENVIRONMENTAL QUALITY BRANCH ENVIRONMENT CANADA 2ND FLOOR, TWIN ATRIA #2 4999-98TH AVENUE EDMONTON, AB. T6B 2X3	468-8010
* BILL KOVACH ENVIRONMENTAL TECHNOLOGIST BYRON CREEK COLLIERIES P. O. BOX 1960 SPARWOOD, BC. V0B 2G0	

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

BRIAN LAJEUNESSE 340-5142
FISH AND WILDLIFE DIVISION
ALBERTA FORESTRY, LANDS AND WILDLIFE
3RD FLOOR, PARKLAND SQUARE
4901-48TH STREET
RED DEER, AB.
T4N 6M4

* FRANCOIS LAPOINTE (819) 953-1562
SEDIMENT SURVEY SECTION, WSC
ENVIRONMENT CANADA
8TH FLOOR, PLACE VINCENT MASSEY
351 ST. JOSEPH BLVD.
HULL, PQ.
K1A 0H3

ALBERT T. LEES 290-7356
ENVIRONMENTAL & QUALITY MANAGEMENT
NOVA, AN ALBERTA CORPORATION
32ND FLOOR
801 - 7TH AVENUE S.W.
CALGARY, AB.
T2P 2N6

RUSSELL LEWIS 247-6611
NANUK ENGINEERING & DEVELOPMENT LTD.
380; 4500-16 AVENUE N.W.
CALGARY, AB.
T3B 0M6

* DR. LARRY LINTON 247-6613
HYDROQUAL
380; 4500-16TH AVENUE N.W.
CALGARY, AB.
T3B 0M6

* ALLAN LOCKE 427-6734
DEPT. OF FORESTRY, LANDS & WILDLIFE
FISH & WILDLIFE DIVISION
HABITAT BRANCH
MAIN FLOOR, N TOWER
9945-108 STREET
EDMONTON, AB.
T5K 2G6

R. J. LOGAN 420-5810
SENIOR ENVIRONMENTAL PLANNER
LUSCAR LTD.
1600 OXFORD TOWER
10235-101ST STREET
EDMONTON, AB.
T5J 3G1

MAILING LIST	TELEPHONE NUMBER
* ATTENDED SEMINAR	
* GREGORY W. MACCULLOCH WATER SURVEY OF CANADA ENVIRONMENT CANADA 854; 220-4TH AVE S.E. BAG 2909, STN "M" CALGARY, AB. T2P 2M7	292-5307
J. N. MACKENZIE J. N. MACKENZIE ENGINEERING LTD. 230; 6025-12TH STREET S.E. CALGARY, AB. T2H 2K1	252-2244
* DR. DAVID H. MANZ DEPT. OF CIVIL ENGINEERING UNIVERSITY OF CALGARY 2500 UNIVERSITY DRIVE N.W. CALGARY, AB. T2N 1N4	220-5503
JACK MARSH SEREDA MARSH & ASSOCIATES LTD. 5418-97TH STREET EDMONTON, AB. T6E 5C1	437-3276
R. T. MARSHALL COAL ASSOCIATION OF CANADA SUITE 502 205-9TH AVENUE S.E. CALGARY, AB. T2G 0R3	262-1544
* L. N. MARTEL WATER RESOURCES BRANCH ENVIRONMENT CANADA 1001 PIERRE-DUPUY STREET LONGUEUIL, PQ. J4K 1A1	(418) 646-1037
* ROBERT MARTEL ALBERTA ENVIRONMENT ENVIRONMENTAL PROTECTION SERVICES POLLUTION CONTROL DIVISION WATER QUALITY CONTROL BRANCH INDUSTRIAL & WATER QUALITY SECTION 6TH FLOOR, OXBRIDGE PLACE 9820-106TH STREET EDMONTON, AB. T5K 2J6	

MAILING LIST	TELEPHONE NUMBER
* ATTENDED SEMINAR	
BERND MARTENS MANALTA COAL LTD. P. O. BOX 2880 CALGARY, AB. T2P 2M7	294-5311
AKIO MASUDA ALBERTA ENVIRONMENT WATER QUALITY CONTROL BRANCH 6TH FLOOR, OXBRIDGE PLACE 9820-106 STREET EDMONTON, AB. T5K 2J6	427-5829
R. DAVID MCBRIDE WATER RESOURCES BRANCH ENVIRONMENT CANADA 5TH FLOOR, QUEEN SQUARE DARTMOUTH, NS. B2Y 2N6	426-5778
* JOSEPH L. MCILHINNEY SEDIMENT SURVEY SECTION WATER SURVEY OF CANADA ENVIRONMENT CANADA 8TH FLOOR, PLACE VINCENT MASSEY 351 ST. JOSEPH BLVD. HULL, PQ. K1A 0H3	(819) 953-3680
CURTIS MCKAY FISHERIES AND OCEANS 852; 220-4 AVENUE S.E. CALGARY, AB. T2G 4X3	292-5858
* BRIAN MELLER ENVIRONMENTAL SCIENCE DEPT. LETHBRIDGE COMMUNITY COLLEGE 3000 COLLEGE DRIVE LETHBRIDGE, AB. T1K 1L6	320-3297
* TIMOTHY C. MILLER U. S. G. S. OFFICE OF WATER QUALITY 412 NATIONAL CENTER 12201 SUNRISE VALLEY DRIVE RESTON, VA. 22092 U. S. A.	(819) 648-6868

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TELEPHONE
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* ATTENDED SEMINAR

JAY MOORE 632-6761
HEAD, AQUATIC BIOLOGY
ALBERTA ENVIRONMENTAL CENTRE
P. O. BOX 4000
VEGREVILLE, AB.
T0B 4L0

* ASH MORJARIA 948-4108
REGIONAL BRIDGE PROJECTS ENGINEER
ALBERTA TRANSPORTATION AND UTILITIES
P. O. BOX 550
AIRDRIE, AB.
T0M 0B0

JOSEPH A. MORELAND (406) 449-5263
DISTRICT CHIEF
UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ROOM 428, FEDERAL BUILDING
301 SOUTH PARK AVENUE, DRAWER 10076
HELENA, MT. 59601
U. S. A.

JOHN A MORRISON 427-6150
DESIGN AND CONSTRUCTION DIVISION
ALBERTA ENVIRONMENT
8TH FLOOR, OXBRIDGE PLACE
9820-106TH STREET
EDMONTON, AB.
T5K 2J6

D. E. (DAVE) MORTIN, P. ENG. 283-4961
UMA ENGINEERING LTD.
2540 KENSINGTON ROAD N.W.
CALGARY, AB.
T2N 3S3

* G. H. MORTON 292-5311
WATER RESOURCES BRANCH
ENVIRONMENT CANADA
854; 220-4TH AVENUE S.E.
BAG 2909; STATION "M"
CALGARY, AB.
T2P 2M7

STEVEN MUENZ 466-9000
INFRASTRUCTURE SYSTEMS LTD.
100; 5008-86TH STREET
EDMONTON, AB.
T6E 5S2

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TELEPHONE
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* ATTENDED SEMINAR

B A. MUNSON
HEAD, INDUSTRIAL CONTAMINANTS SECTION
ENVIRONMENTAL PROTECTION
ENVIRONMENT CANADA
TWIN ATRIA #2, ROOM 210
4999-98TH AVENUE
EDMONTON, AB.
T6B 2X3

F. MARLIN MURPHY 692-3967
GREGG RIVER RESOURCES LTD.
BAG 5000
HINTON, AB.
T0E 1B0

DR. IVAN MUZIK 220-6189
DEPT. OF CIVIL ENGINEERING
UNIVERSITY OF CALGARY
2500 UNIVERSITY DRIVE N.W.
CALGARY, AB.
T2N 1N4

* ROBERT MYSLIK (519) 821-0110
WATER RESOURCES BRANCH
ENVIRONMENT CANADA
75 FARQUHAR STREET
GUELPH, ON.
N1H 3N4

JAY NAGENDRAN
ALBERTA ENVIRONMENT
WATER QUALITY BRANCH
STANDARDS AND APPROVALS DIVISION
4TH FLOOR, OXBRIDGE PLACE
9820-106TH STREET
EDMONTON, AB.
T5K 2J6

C. R. (CHARLIE) NEILL 436-5868
NORTHWEST HYDRAULICS CONSULTANTS LTD.
4823-99 STREET
EDMONTON, AB.
T6E 4Y1

R. DAVID NEILSON 422-4385
FARM WATER MANAGEMENT SECTION
CONSERVATION & DEVELOPMENT BRANCH
ALBERTA AGRICULTURE
J. G. O'DONOGHUE BLDG., 2ND FLOOR E.
206; 7000-113 STREET
EDMONTON, AB.
T6H 5T6

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

LYLE NELSON 267-4969
WATER MANAGEMENT GROUP
TRANSALTA UTILITIES CORP.
BOX 1900
CALGARY, AB.
T2P 2M1

LEE NELSON 653-2417
MOUNTAINVIEW IRRIGATION DISTRICT
MOUNTAINVIEW, AB.
T0K 1N0

WAYNE NELSON
ALBERTA FORESTRY, LANDS & WILDLIFE
FISH & WILDLIFE DIVISION
P. O. BOX 1450
ST. PAUL, AB.
T0A 3A0

* CLEMENT NG
ALBERTA ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICES
WATER QUALITY CONTROL BRANCH
INDUSTRIAL & WATER QUALITY SECTION
6TH FLOOR, OXBRIDGE PLACE
9820-106TH STREET
EDMONTON, AB.
T5K 2J6

VICTOR NIEMELA (819) 997-1920
DIRECTOR
WATER QUALITY BRANCH
7TH FLOOR, PLACE VINCENT MASSEY
351 ST. JOSEPH BLVD.
HULL, PQ.
K1A 0H3

ALLEN NIP 962-8700
ALBERTA FOREST SERVICE
RESEARCH BRANCH
BOVILE BUILDING
215 MCLEOD AVENUE
SPRUCE GROVE, AB.
T7X 2Y4

DR. LAWRENCE NKindrem 220-5584
DEPT. OF GEOGRAPHY
UNIVERSITY OF CALGARY
2500 UNIVERSITY DRIVE N.W.
CALGARY, AB.
T2N 1N4

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

JOHN. O. H. NUNN 400 MONENCO PLACE 801-6TH AVENUE S.W. CALGARY, AB. T2P 3W3	298-4615
* MS. BILLIE O'BRIEN FORDING COAL LTD. BOX 100 ELKFORD, BC. V0B 1M0	(604) 362-1212
* MICHAEL T. O'TOOLE CARDINAL RIVERS COAL LTD. BAG SERVICE 2570 HINTON, AB. T0E 1B0	692-3763
ALAIN PARE PULSEARCH 51 CASTLERIDGE RD N.E. CALGARY, AB. T3J 1N8	259-8560
RONALD PARRISH BOLTER PARISH TRIMBLE LTD. 201; 17220 STONEY PLAIN ROAD EDMONTON, AB. T5G 1K6	489-6671
BRENT PATERSON ALBERTA AGRICULTURE LAND EVALUATION & RECLAMATION BRANCH AGRICULTURE CENTRE JAIL ROAD LETHBRIDGE, AB. T1J 4C7	381-5338
KEN PERL ENVIRONMENTAL SCIENCE DEPT. LETHBRIDGE COMMUNITY COLLEGE 3000 COLLEGE DRIVE LETHBRIDGE, AB. T1K 1L6	320-3252

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

WAYNE PETTAPIECE AGRICULTURE CANADA SOIL SURVEY SECTION SUITE 653, TERRACE PLAZA TOWER 4445 CALGARY TRAIL SOUTH EDMONTON, AB. T6H 5R7	495-4243
DON PETTEY KLOHN LEONOFF LTD. 15; 6320 - 11TH STREET S.E. CALGARY, AB. T2H 2L7	259-4114
R. PHAFF ROSS CREEK IRRIGATION DISTRICT P. O. BOX 576 MEDICINE HAT, AB. T1A 7G5	527-0208
MIKHAIL (MIKE) PILDYSH PILDYSH CONSULTING SERVICES LTD. 35 BEDDINGTON RISE N.E. CALGARY, AB. T3K 1N1	259-3559
E. T. PODIVINSKY CITY OF EDMONTON WATER & SANITATION 3RD FLOOR, WEST CHAMBERS 12220 STONY PLAIN ROAD EDMONTON, AB. T5N 3Y4	428-5747
AKOS PUNGOR ALBERTA AGRICULTURE IRRIGATION BRANCH AGRICULTURE CENTRE JAIL ROAD LETHBRIDGE, AB. T1J 4C7	381-5338
* ROBERT QUAZI ALBERTA ENVIRONMENT RIVER ENGINEERING BRANCH 10TH FLOOR, OXBRIDGE PLACE 9820-106 STREET EDMONTON, AB. T5K 2J6	427-6282

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

DR. BRUCE RAINS 432-3564
DEPT. OF GEOGRAPHY
UNIVERSITY OF ALBERTA
3-127 TORY BUILDING
EDMONTON, AB.
T6G 2H4

* JAY G. RAMOTAR 427-6916
BRIDGE PLANNING
ALBERTA TRANSPORTATION AND UTILITIES
BRIDGE ENGINEERING BRANCH
4999-98TH AVENUE
EDMONTON, AB.
T6B 2X3

* ARTHUR REDSHAW (403) 920-8501
CHIEF, NWT PROGRAMS
INLAND WATERS DIRECTORATE
ENVIRONMENT CANADA
P.O. BOX 2970
YELLOWKNIFE, NWT.
X1A 2R2

GUS RIBEIRO 452-0090
ECOS ENGINEERING SERVICES LTD.
201; 11133-124 STREET
EDMONTON, AB.
T5M 0J2

CLIFF REDELBACK 362-3161
EASTERN IRRIGATION DISTRICT
P. O. BOX 8
BROOKS, AB.
T0J 0J0

* GREGORY REINHARDT 252-2244
J. N. MACKENZIE ENGINEERING LTD.
230; 6025-12TH STREET S.E.
CALGARY, AB.
T2H 2K1

RON L. RENWICK 328-4401
ST. MARY RIVER IRRIGATION DISTRICT
1210-36 STREET NORTH
P. O. BOX 278
LETHBRIDGE, AB.
T1J 3Y7

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

D. T. RICHMOND, P. ENG.
27 GILMORE CRESCENT
ST. ALBERT, AB.
T8N 1B2

FREDERICK A. ROSS
GENERAL MANAGER, LNIID
334-13TH STREET N
LETHBRIDGE, AB.
T1H 2R8

327-3302

RICHARD ROTHWELL
UNIVERSITY OF ALBERTA
DEPT. OF FOREST SCIENCE
GENERAL SERVICES BUILDING
8TH FLOOR, ROOM 867
EDMONTON, AB.
T6G 2G6

432-4413

GERALD SAMIDE
SAMIDE ENGINEERING LTD.
204; 9924-106 STREET
EDMONTON, AB.
T5K 1C4

426-3109

* LES SAWATSKY
W-E-R ENGINEERING LTD.
306; 2735 - 39TH AVENUE N.E.
CALGARY, AB.
T1Y 4T8

291-1195

* DR. ROBERT C. SCACE
SCACE & ASSOCIATES LTD.
BOX 7156, STN "E"
CALGARY, AB.
T3C 3M1

246-8303

WINFRIED SCHENK
ALBERTA FORESTRY, LANDS & WILDLIFE
FISH & WILDLIFE DIVISION
SAM LIVINGSTON FISH HATCHERY
1440-17A STREET S.E.
CALGARY, AB.
T2G 4T9

297-6561

MAILING LIST	TELEPHONE NUMBER
* ATTENDED SEMINAR	
JOHN SEALY CITY OF CALGARY MUNICIPAL BUILDING P. O. BOX 2100, STATION "M" CALGARY, AB. T2P 2M5	268-2183
* DR. READ SEIDNER CITY OF CALGARY WATERWORKS DIVISION - 35 P. O. BOX 2100 CALGARY, AB. T2P 2M5	268-5721
* BEVERLY SIKORSKI WATER RESOURCES BRANCH ENVIRONMENT CANADA 210; 1102-8TH AVENUE REGINA, SK. S4R 1C9	(306) 780-6077
* C. P. S. SIMONSEN HEAD, HYDRAULICS DEPT. ACRES INTERNATIONAL LTD. 500; 10201 SOUTHPORT ROAD S.W. CALGARY, AB. T2W 4X9	253-9161
JOHN H. SIMPSON ALBERTA ENVIRONMENT HEAD, PLANNING SERVICES BRANCH PLANNING DIVISION 9TH FLOOR, OXBRIDGE PLACE 9820-106 STREET EDMONTON, AB. T5K 2J6	427-2375
JOHN SLATER THE SNC GROUP SUITE 203, LACIDEM BLDG. 542-7TH STREET SOUTH LETHBRIDGE, AB. T1J 2H1	320-8886
* E. J. W. SLIMMON WATER SURVEY OF CANADA ENVIRONMENT CANADA 854; 220-4TH AVE S.E. BAG 2909, STN "M" CALGARY, AB. T2P 2M7	292-5307

MAILING LIST	TELEPHONE NUMBER
* ATTENDED SEMINAR	
RICHARD SLOPEK 400 MONENCO PLACE 801-6TH AVENUE S.W. CALGARY, AB. T2P 3W3	298-4615
* BARRY SMITH WATER RESOURCES BRANCH ENVIRONMENT CANADA 75 FARQUHAR STREET GUELPH, ON. N1H 3N4	(519) 821-0110
DR. D. (DERALD) G. SMITH DEPT. OF GEOGRAPHY UNIVERSITY OF CALGARY CALGARY, AB. T2N 1N4	220-6191
* MILTON O. SPITZER REGIONAL ENGINEER WATER RESOURCES BRANCH ENVIRONMENT CANADA 854; 220-4TH AVENUE S.E. BAG 2909; STATION "M" CALGARY, AB. T2P 2M7	292-5317
JIM STELFOX ALBERTA FORESTRY, LANDS & WILDLIFE FISH & WILDLIFE DIVISION 200 SLOANE SQUARE 5920-1A STREET S.W. CALGARY, AB. T2H 0G3	297-6423
PETER STEVENS STANLEY ASSOCIATES ENGINEERING LTD. 10160-112TH STREET EDMONTON, AB. T5K 2L6	423-4777
GEORGE STERLING P. O. BOX 3008 EDSON, AB. T0E 0P0	723-2838

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

ALAN STEWART PFRA AGRICULTURE CANADA 4TH FLOOR, CORNERPOINT BLDG. 10179-105 STREET EDMONTON, AB. T5J 1E2	495-3307
ROBERT (BOB) STONE ALBERTA ENVIRONMENT ENVIRONMENTAL ASSESSMENTS DIVISION 11TH FLOOR, OXBRIDGE PLACE 9820-106TH STREET EDMONTON, AB. T5K 2J6	427-6224
R. H. SWANSON NORTHERN FOREST RESEARCH CENTRE AGRICULTURE CANADA 5320-122 STREET EDMONTON, AB. T6H 3S5	435-7241
GARY SYKES 48 BAKER CRES N.W. CALGARY, AB. T2L 1R4	282-0405
ANIKO E. M. SZOJKA 710-52ND AVENUE S.W. CALGARY, AB. T2V 0B5	255-6032
BRUNO TASSONE WATER RESOURCES BRANCH ENVIRONMENT CANADA 502; 1001 WEST PENDER STREET VANCOUVER, BC. V6E 2M9	(604) 666-6207
BRUCE TAYLOR ALBERTA ENVIRONMENT WASTES & CHEMICALS DIVISION 5TH FLOOR, OXBRIDGE PLACE 9820-106TH STREET EDMONTON, AB. T5K 2J6	427-5855

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

DICKSON THOMPSON 220-6601
 FACULTY OF ENVIRONMENTAL DESIGN
 UNIVERSITY OF CALGARY
 2500 UNIVERSITY DRIVE N.W.
 CALGARY, AB.
 T2N 1N4

* MIKE THOMPSON 247-6611
 NANUK ENGINEERING & DEVELOPMENT LTD.
 380; 4500-16 AVENUE N.W.
 CALGARY, AB.
 T3B 0M6

GORDON TOFTE (604) 666-3606
 WATER RESOURCES BRANCH
 ENVIRONMENT CANADA
 1001 WEST PENDER STREET
 VANCOUVER, BC.
 V6E 2M9

* ANNETTE M. TRIMBEE 427-2375
 ACTING HEAD,
 ENVIRONMENTAL ASSESSMENT SECTION
 PLANNING SERVICES BRANCH
 ALBERTA ENVIRONMENT
 9TH FLOOR, OXBRIDGE PLACE
 9820-106TH STREET
 EDMONTON, AB.
 T5K 2J6

* DENNIS TROTTER 298-4585
 MONENCO CONSULTANTS LTD.
 7TH FLOOR, MONENCO PLACE
 801 - 6TH AVENUE S.W.
 CALGARY, AB.
 T2P 3W3

DOUGLAS TUPPER 427-6215
 ALBERTA ENVIRONMENT
 WATER RESOURCES ADMINISTRATION
 3RD FLOOR, OXBRIDGE PLACE
 9820-106TH STREET
 EDMONTON, AB.
 T5K 2J6

DR. NICK TYWONIUK 468-8063
 ENVIRONMENT CANADA
 TWIN ATRIA #2, 2ND FLOOR
 4999-98TH AVENUE
 EDMONTON, AB.
 T6B 2X3

MAILING LIST

TELEPHONE
NUMBER

* ATTENDED SEMINAR

* NEIL VANDER GUGTEN SNC GROUP 10130-103RD STREET EDMONTON, AB. T5J 3N9	422-6288
HANK VANDER PLUYM CONSERVATION AND DEVELOPMENT BRANCH ALBERTA AGRICULTURE AGRICULTURE CENTRE LETHBRIDGE, AB. T1J 4C7	381-5538
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RALPH WALTERS ALBERTA TRANSPORTATION BRIDGE PLANNING SECTION BRIDGE ENGINEERING BRANCH 3RD FLOOR, TWIN ATRIA BLDG. 4999-98 AVENUE EDMONTON, AB. T6B 2X3	427-6916

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* LYMAN A. WARNER HYDROLOGY DIVISION WATER RESOURCES BRANCH ENVIRONMENT CANADA 854; 220-4TH AVENUE S.E. BAG 2909, STATION "M" CALGARY, AB. T2P 2M7	292-5406
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* JIM G. WAY REGIONAL ENGINEER WATER RESOURCES BRANCH ENVIRONMENT CANADA 521; 269 MAIN STREET WINNIPEG, MB. R3C 1B2	(204) 983-3652
GRANT WOOD AETNA IRRIGATION DISTRICT P. O. BOX 340 CARDSTON, AB. T0K 0K0	653-4441
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* RICHARD YUNGWIRTH WATER RESOURCES BRANCH ENVIRONMENT CANADA 210; 1102-8TH AVENUE REGINA, SK. S4R 1C9	(306) 780-5348

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- * TED R. YUZYK (819) 953-1561
SEDIMENT SURVEY SECTION
WATER SURVEY OF CANADA
ENVIRONMENT CANADA
8TH FLOOR, PLACE VINCENT MASSEY
351 ST. JOSEPH BLVD.
HULL, PQ.
K1A 0H3
- GORDON ZOBELL 752-3511
RAYMOND IRRIGATION DISTRICT
P. O. BOX 538
RAYMOND, AB.
T0K 2G0
- * PHILIP ZRYMIAK (819) 953-3679
SEDIMENT SURVEY SECTION
WATER SURVEY OF CANADA
ENVIRONMENT CANADA
8TH FLOOR, PLACE VINCENT MASSEY
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